

BONE PRODUCTS AND MANURES

*An Account of the Most Recent Improvements in the
Manufacture of Fat, Glue, Animal Charcoal
Size, Gelatine, and Manures*

BY

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PREFACE.

IN the present volume, the author has endeavoured to place before manufacturers, students of technology, and others interested, a practical and comprehensive account of the modern method of fat extraction and the manufacture of glue, size, gelatine, manures, etc.

This branch of industry is undergoing considerable change. Old and wasteful methods of working are giving way to newer processes, based on the application of chemical science, which is becoming more and more important in this as in other industries. The book is arranged in nine chapters, and is fully illustrated with drawings of the most modern type of plant.

To enhance the value of the work, the author has devoted a chapter exclusively to a description of the methods of analysis of both raw and finished products, with the hope that it will be of service to chemists engaged in this department of industry.

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BONE PRODUCTS AND MANURES.

PART I.

BONE PRODUCTS.

CHAPTER I.

THE TREATMENT OF BONES.

REGARDED from a chemical point of view, the framework supporting the fleshy tissues of animals, which we call bone, is composed mainly of the phosphates of lime and magnesia, with smaller proportions of carbonate of lime, and alkaline salts, united with fatty and cartilaginous matter. From the latter we obtain a considerable proportion of our glue; while the fatty matter is extracted as bone fat, and the phosphates constitute the basis of our manure trade.

Bone cartilage is composed of carbon, hydrogen, oxygen, and nitrogen; the percentage composition being practically constant whether the cartilage is from an old or young animal, as may be seen from the following analyses by Fremy:—

Cartilage from	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Ox, old . .	49·81%	7·14%	17·32%	25·67%
Calf . .	49·9%	7·3%	17·2%	25·6%

The bones of the young are, however, much richer in cartilage than those of the old. This is reversed in the

case of the inorganic or mineral matter, the old containing a greater proportion of phosphates.

Then again, the fatty matters are present to a greater extent in full-grown animals than in those of the young; also from the thigh and leg bones the yield is higher than from the heads, ribs, or shoulder-blades, the amount of fat in the latter averaging 12 or 13 per cent., whilst in the former it rises to 18 or 19 per cent.

To separate the different classes of bones coming into a works and arrange them according to the amounts they would produce of fat and glue would be desirable, but in practice this is never carried out; it would be tedious work for a manufacturer to separate, say, the bones of sheep, calves, oxen, horses, or pigs, and subdivide these again into heads, ribs, breasts, shoulders, feet, etc. Bones are mainly bought by contract from various dealers in towns within easy railway access to the works, the rates being generally fixed for twelve months, to cover all classes of common bones, whether fresh butchers' or a mixture with partly boiled bones. The only discrimination made is with the marrows, which are bagged separately, and bring as much as 6s. 6d. per cwt. Bones differ considerably in their value; fresh bones yield the highest percentage of fat and glue; on the other hand, the writer has found only 6 per cent. of fat together with 30 per cent. of water in partly boiled bones. Sometimes hoofs, horns, iron, beefy matter, and even pieces of brick are included; naturally these add to the weight, but, excepting the horns, they have no value. With careful sorting, these adulterants are detected, and a reduction in the weight is made accordingly. The manufacturer is, as a rule, open to treat for material from all sources: it may be putrid ham or bacon from the provision merchant's store, diseased fatty meat condemned by a zealous inspector, and even infected pigs, slaughtered by official order; these are all brought at

times to the mouth of the benzene extractor ; also the writer has seen a cargo of cotton seed, damaged by water, treated for extraction of the oil by the benzene process.

The arrangement and situation of a bone factory is a matter of great importance. The works should have easy access to main lines of railway, with ample siding accommodation ; a canal connection would also be of advantage. A plentiful supply of water and a good outflow for all effluents are a necessity. In fixing upon the site, a position outside the boundaries of a town should be chosen, so that the offensive smell which arises from a works of this character may not be made a matter of complaint by a populous community. The lighting of the works is another consideration ; probably the district has no gas connection with a town, it may then be advisable to fit up a complete electric installation, lighting, say, 140 to 150 lamps. On the other hand, if the bones are carbonised for the making of "char," there is available a large volume of uncondensable gases of high illuminating power, which, after purification, can be stored in a gasometer, for ultimate use in lighting the works and probably also as a motive power for driving machinery.

In arranging the works, the benzene house, with its storage accommodation for benzene, should be placed apart from the main buildings, and the crushed bones carried by an elevator to the charging floor. The plant should be arranged so that the different processes can be carried through with a minimum of labour, quick transition between each being essential, and every facility for loading the finished goods.

The raw bones, which at times are very heavily charged with moisture, should not be allowed to accumulate for any length of time, as they soon begin to smell strongly ; the cartilage turns black from decomposition, which means a loss in the ultimate yield of and also deterioration in the

quality of the glue. The first operation is that of sorting; the bones being thrown upon a table, from which they are fed to a crusher or "cracker". Here several women are constantly engaged separating the rags, iron, beefy matter, hoofs, horns, etc. As they are sorted the bones are pushed to the mouth of the crusher, thence falling between fixed and revolving steel "cutters," which break them into pieces three to four inches long. This enables the benzene in the subsequent process to penetrate to the centre of the bone. Falling on to an elevator, the crushed bones are carried to the charging floor of the benzene house.

In Figs. 1, 2, and 3 the most modern type of degreasing plant is shown in longitudinal section, plan, and section respectively. The house is what is termed a "100-ton house,"—that is, the plant is capable of degreasing 100 tons of bones in five working charges. *AA* are the two extractors, each holding about ten tons. These are built of the best mild steel, and fitted with perforated false bottoms, underneath which rest the dry and wet steam coils supplied by the pipes *NN*. In each there is a manhole at *JJ*, through which the extractors are emptied, the degreased bones being carried away to another part of the works by the "bogey" railway, shown in the plan. Both extractors have inlet naphtha pipes *FF*, which are fed from the two large storage tanks *BB*. The outlet pipes for the naphtha vapours are at *EE*, the vapours thence passing into the condensers *CC*. Each condenser is divided into five divisions, connected with one another so that the circulation of water is complete over the whole. The inlet pipes to the condensers are 6-in. diameter, and this bore is gradually reduced to 2½-in. diameter in the outlet pipes *GG*, which carry the condensed naphtha and water to the Florentine receivers or separators *DD*. Here, owing to the difference in gravity, the separation between the two liquids is instantaneous, the water leaving by the pipes *II*, the naphtha

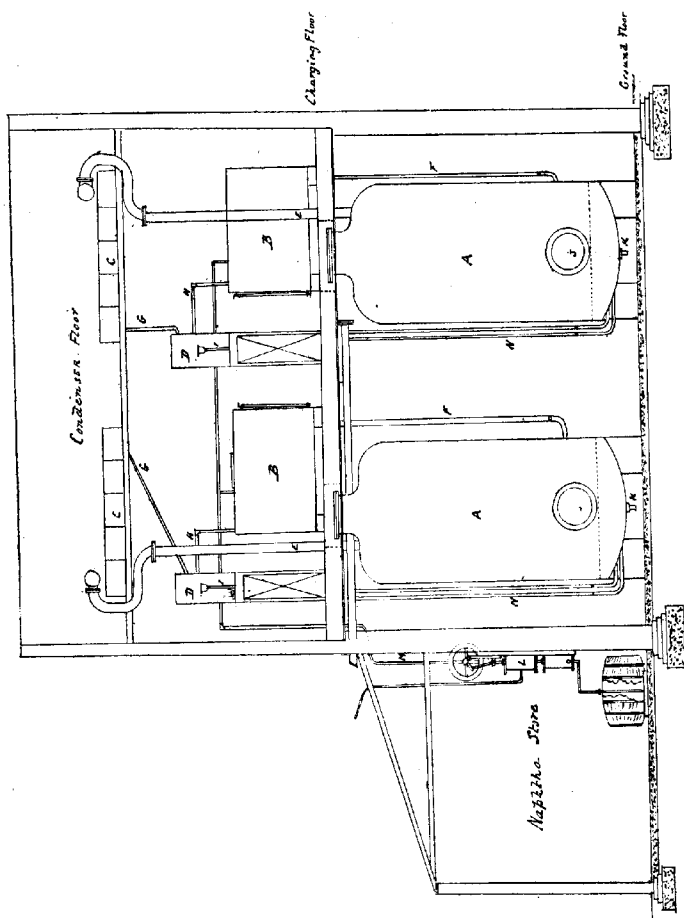


FIG. 1.—Benzene Extraction Plant. Longitudinal Section.

passing through *HH* to the storage tank, to be passed again over the charge in the extractors.

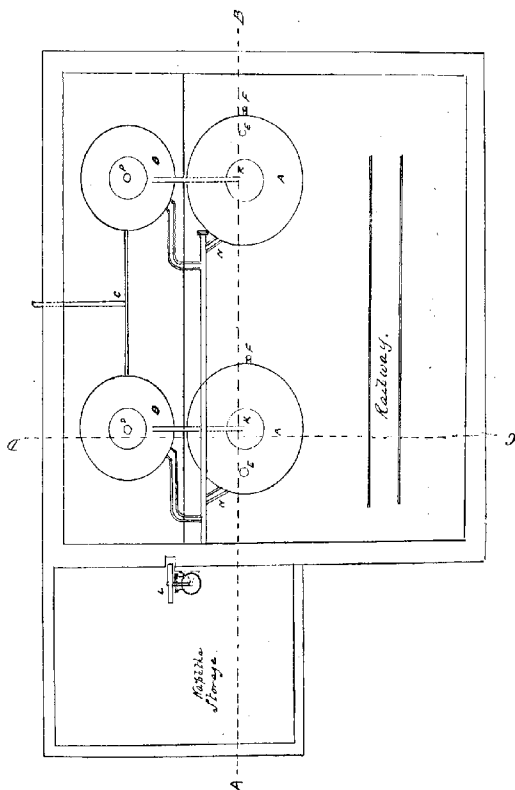


FIG. 2.—Benzene Extraction Plant Plan.

The naphtha store is shown at the end of the building, and contains the pumping-engine *L*, which lifts the naphtha from the barrels, through the pipe *M*, up to the storage tanks.

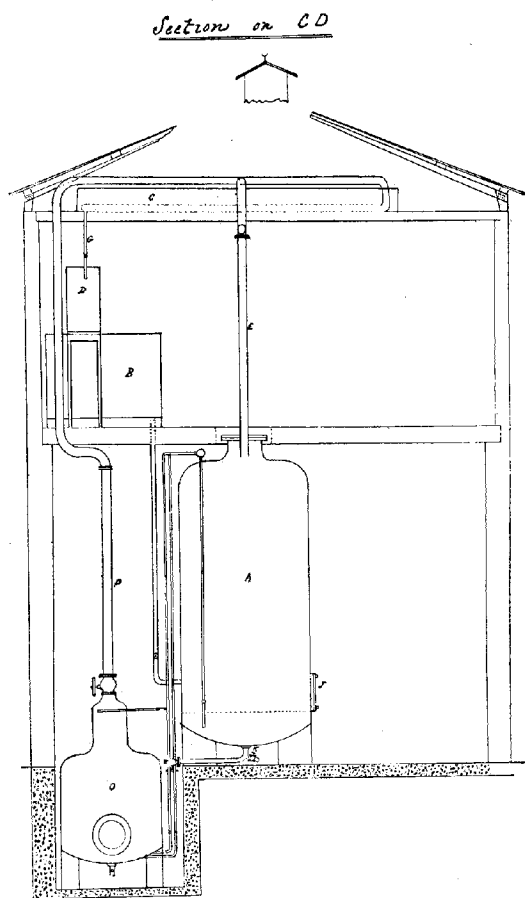


FIG. 3.—Benzene Extraction Plant. Cross Section.

In the section and plan is seen the position of the *mont-jus* or distiller, into which is run the fat from the extractor at *K*. The fat retains a fair proportion of naphtha, and the work of the *mont-jus* is to distil this over, the vapours passing through the pipe *P*, entering the condenser *C*. The fat is then blown up by steam to an outside vat, and flows from thence to the clarifying vats in the main buildings of the works.

The quality of benzene used is a matter of considerable importance to the manufacturer. The term "benzene" is a general one, applied to both American and Russian petroleum, Scotch shale oils, solvent naphthas, etc. The value for extractive purposes of a "benzene" is based on the boiling-point and the proportion which distills over between certain temperatures. If a benzene with a low boiling-point be used, a large percentage distilling over below the boiling-point of water (212° F.), then the action in the extractor becomes too rapid, the benzene being distilled over before it has time to do its work as a solvent, consequently the bones after treatment remain moist, and retain probably 3 to 4 per cent. of fat. On the other hand, if a benzene with a high boiling-point be used, a large proportion of it fractionating over above 270° F., then the operation takes longer in the extractor, a greater steam pressure being necessary to drive over the heavy hydrocarbons of the oil, which may not distil until a temperature of 330° to 340° F. is reached. This prolonged high steam pressure has a deleterious effect on the cartilaginous matter of the bone, thus lessening the quantity, and injuring the quality of the glue produced.

A good working benzene should boil at or about 212° F., with little or nothing coming over below that temperature, while at 270° F. 98 to 99 per cent. should distil over, leaving 1 to 2 per cent. to be driven off between 270° and 280° F.

The following four fractionations illustrate the differences in the value of naphthas for extraction purposes.

No. 1. Boiling-point, 212° F.	
Below 212° F.	0 per cent.
212° to 220° F.	14 "
220° to 230° F.	20½ "
230° to 240° F.	38 "
240° to 250° F.	16½ "
250° to 260° F.	6 "
260° to 270° F.	4 "
270° to 280° F.	1 "
Over 280° F.	0 "

No. 2. Boiling-point 212° F.	
Below 212° F.	0 per cent.
212° to 220° F.	6 "
220° to 230° F.	31 "
230° to 240° F.	40 "
240° to 250° F.	20 "
250° to 260° F.	2 "
260° to 270° F.	1 "
Over 270° F.	0 "

No. 3. Boiling-point, 180° F.	
180° to 192° F.	63 per cent.
192° to 212° F.	26 "
212° to 230° F.	8 "
230° to 260° F.	3 "
Over 260° F.	0 "

No. 4. Boiling-point, 234° F.	
200° to 234° F.	8 per cent.
234° to 250° F.	23 "
250° to 260° F.	18 "
260° to 270° F.	15 "
270° to 280° F.	12 "
280° to 290° F.	9 "
290° to 300° F.	5 "
Over 300° F.	11 "

In the practical working of these naphthas, Nos. 1 and 2 would give the best results, leaving a dry, well-degreased bone and the cartilage practically untouched.

No. 3 would leave the cartilage unattacked, but the bone would retain an appreciable amount of moisture and fat.

With No. 4, although the bone would be well degreased, the time of extraction would be longer than with Nos. 1 and 2, also with the greater steam pressure required it would injure the cartilage for subsequent glue-making.

A peculiar property possessed by benzene is that, if allowed to remain in contact with bones for several hours, it has the power of dissolving not only the fat, but also of acting upon and partly dissolving the cartilaginous matter; thus the plan of steeping the bones in the hydrocarbon for several hours, and then distilling over, produces a fat carrying with it a proportion of cartilaginous matter, which not only means a loss, but is very difficult to separate in the after clarification of the fat. Improvements have been made on this method by American manufacturers who have adopted a plan of allowing the hydrocarbon to trickle through the mass. It is, however, to the German manufacturers that we are indebted for a perfected system of grease extraction, about which little is known in this country. So economical is the system in its working, that bones can be degreased leaving only $\cdot 2$ to $\cdot 4$ per cent. of fat unextracted, and the loss of benzene calculated on the weight of bones used is as low as $\cdot 4$ per cent., which includes the benzene lost in working as well as that left in the crude fat. In eight different trials with common bones and knuckle-ends, the latter originally containing 18 to 19 per cent. fat, the author found after extraction the following:—

(1)	(2)	(3)
$\cdot 29$ per cent. fat.	$\cdot 31$ per cent. fat.	$\cdot 17$ per cent. fat.
(4)	(5)	(6)
$\cdot 46$ per cent. fat.	$\cdot 41$ per cent. fat.	$\cdot 38$ per cent. fat.
(7)	(8)	
$\cdot 50$ per cent. fat.	$\cdot 27$ per cent. fat.	

In working the extractor, particular care must be taken that each valve is open or shut as necessity demands, and the operation is commenced by allowing the benzene to flow from the storage tank to the extractor, until a depth of about twelve inches in the gauge-glass is reached. Meanwhile the steam is slowly admitted and, gradually warming the mass, distillation commences, made evident by the thin stream of benzene and water which passes over into the separator. The remaining benzene in the tank is now allowed to slowly flow into the extractor, and the volume of steam increased by opening wider the valve. Gradually the flow of benzene and water from the condenser increases, and the separated naphtha rises in the storage tank. On taking the temperature at this point, a good indication may be obtained as to whether the action is too rapid or too slow. When the distilled naphtha in the gauge-glass reaches a depth of 27 to 28 inches, the valves are closed, and the first run of fat is made to the *mont-jus*. A fresh charge of naphtha is then run into the extractor, and the naphtha feed-pipe kept a quarter open, so that the remaining portion from the storage tank trickles slowly into the mass of bones, the storage tank meanwhile being replenished by the distillation proceeding in the extractor. The naphtha, after condensation, leaving the extractor is greater than in entering, consequently the storage tank is again slowly filled. By these operations the naphtha is continually on the move and never quiescent. At the height of 27 to 28 inches the valves are closed, and the *mont-jus* receives its second supply of fat, which, as a matter of course, is less in quantity than the first run. The operation is repeated a third time, forming the final charge, and the extracted fat, as before, is run to the *mont-jus*. The bones still retain a portion of the naphtha, along with some moisture, to remove which and render the bones thoroughly dry, high-pressure steam is blown through the

extractor until the very faintest of naphtha films only is noticed floating on the condenser liquor. This indicates that practically all the naphtha is driven over, and the operation may then be considered as finished. Thereupon the manholes are opened, the imprisoned steam allowed to escape, the charge being then found in a thoroughly dried condition and ready for removal to the "bogy" railway. The weight obtained will be equal to about 60 per cent. of the total weight of raw bones used.

As previously explained, the crude fat is run off at three different stages during the extraction, carrying with it some 5 to 10 per cent. of naphtha, together with a certain proportion of water, fine phosphatic matter, and dirt from the bones. The steam is turned on the *mont-jus* and the fat boiled, the escaping naphtha passing through a 6-inch pipe to the condenser above. At the separator the workman carefully watches the decreasing flow of benzene, and when this practically ceases, the outlet valve is closed and steam injected to about 5 lb. pressure, which blows the fat through a 3-inch pipe to a large reserve tank placed outside the building. It may be said here that in boiling the fat in the *mont-jus* great care is necessary to prevent violent frothing, which would carry a portion of the fat up the outlet pipe to the condenser. To obviate this, a 1-inch perforated steampipe is fixed within the dome, and when the frothing commences it is kept under control by injecting a little steam through this spray pipe. The crude fat obtained is tested daily for any benzene that it may contain. The proportion of benzene in five samples drawn at different times was found to be as follows:—

1st	.	.	.	.	.	15 per cent. benzene.
2nd	.	.	.	.	.	17 "
3rd	.	.	.	.	.	09 "
4th	.	.	.	.	.	11 "
5th	.	.	.	.	.	18 "

A sample of the crude fat yielded the following figures on analysis :—

Fat	87.22 per cent.
Dirt	4.86 „
Mineral matter	3.67 „
Water	4.12 „
Naphtha . . . . .	.13 „

With proper precautions and care in the working, the percentage of benzene left in the crude fat should not exceed the above results. In the after process of clarification it is eliminated. To refine this crude product, a further boiling with steam and water is necessary, which is performed in open vats, the impurities being allowed to subside, and the clear fat then run into casks for the market. The average yield is about $12\frac{3}{4}$ per cent. on the raw bones used. Bone fat thus produced is darker in colour than that made by boiling or steaming the bones, and some samples retain a very faint smell of naphtha. In the after process of bleaching this is entirely removed, and the colour brought to a good creamy white. To the stearine and glycerine manufacturers, however, colour is not important, therefore it is sold to them in its unbleached condition. The stearine maker buys according to its "titer" and impurities, but more especially the latter, which are limited to 2 per cent. These impurities are specified in the following analyses of the crude fat :—

	(1)	(2)	(3)	(4)
Moisture	1.38%	1.03%	.84%	1.40%
Naphtha . . . . .	.06%	.13%	.08%	.07%
Organic matter other than fat	.09%	.27%	.63%	.18%
Mineral matter (Ash) . . . . .	.16%	.19%	.41%	.15%
Free fatty acids	31.14%	33.85%	37.11%	32.05%

For bleaching the fat several methods have been suggested, among which may be noted the action of air driven in finely

divided streams through the fat heated to 190° or 200° F., as advocated by Dunn. Another process consists in the addition of chlorate of potash in the proportion of '2 per cent. of the fat used, along with a small quantity of sulphuric acid. The use of "permanganate" finds favour as a bleaching agent, the fat being heated to about 200° F., and the "permanganate" dissolved in a little water, added together with dilute sulphuric acid sufficient to render the whole slightly acid. After heating for two hours water is added, and the liquor boiled. This is repeated several times, until the wash water is entirely free from colour.

A simple chemical reaction underlies the well-known bichromate method of Watts. Water glass has also been suggested for clarifying and bleaching of fats. To 1 ton of the fat brought to the boil one-fourth its weight of water is added, 40 lbs. of sodium silicate (water glass) at 50° T., and 10 lbs. of bicarbonate of soda. During the boiling, the dirt and other foreign matter comes to the surface, and is removed by skimming. When the froth appears white the boiling is stopped, cold water added, and the whole allowed to rest for forty-eight hours. The fat is then removed to another vat, boiled with a fresh quantity of water, allowed to settle, and the clear fat run into coolers.

The degreased bones leaving the benzene house are carried by the railway to the mechanical cleanser. In Fig. 4 is shown a longitudinal section of such a cleanser with the receiving den underneath. The cleanser is a large cylindrical drum open at both ends, and covered with a strong 10-mesh wire netting. The bones are lifted by a bucket elevator, falling into a hopper which feeds the cleanser, and are carried by the revolving motion to the farther end, whence they fall into a "shute". Into the den below the coarse meal falls after passing through the netting. Four samples of this meal drawn at different times gave—

	Phosphoric Acid, equivalent to Tribasic Phosphate of Lime.	Nitrogen.
(1)	30.25 per cent.	6.22 per cent.
(2)	26.18 "	4.79 "
(3)	32.37 "	5.85 "
(4)	29.15 "	5.12 "

The whole of the nitrogen is not glue-forming,—that is, it is not solely derived from cartilaginous matter ; a considerable proportion is contained in the hairy matter of skins, etc.,

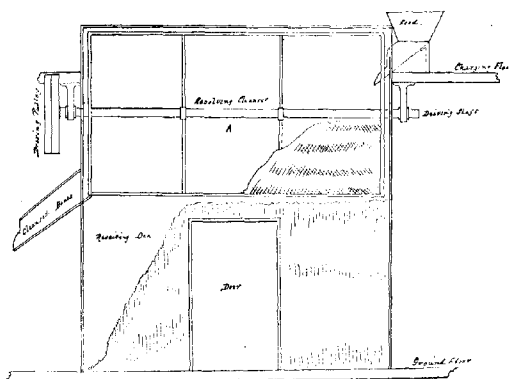


FIG. 4.—Mechanical Cleanser.

which are connected to the bone, or pass in a loose state into the extractor. Still the meal retains a large proportion of nitrogen, which would be more profitably converted into glue than sold for the price of bone meal. The weight of coarse meal averages 14 per cent. on the bones used. This represents an appreciable loss of nitrogen to the glue manufacturer, therefore to save some of this nitrogen, the coarse meal is passed through a smaller revolving cleanser, covered with a 30-mesh netting. Here fully half the weight is separated, and as it leaves the end of the cleanser it is bagged and

passed on to the glue-house for further treatment. The fine dust or flour passing through the 30-mesh screen is sold, or is used in the manure department of the works. Three samples of the fine flour gave on analysis the following results:—

	(1)	(2)	(3)
Phosphoric Acid, equivalent to tribasic phosphate of lime	24.35%	26.29%	23.44%
Nitrogen	1.67%	1.14%	1.07%

The gain in a second cleansing is seen in the considerable diminution of the nitrogen, which means an increase in the weight of glue yielded.

ANIMAL CHARCOAL.

The degreased and cleansed bones are either used by the manufacturer for making glue, with boiled bones as a by-product, for further conversion into superphosphates, or may be converted direct into charcoal, with the subsidiary products of pitch, sulphate of ammonia, etc. A third course is open, that is, to partly degelatinise the bones, extracting 10 per cent. of the carbonaceous and nitrogenous matter as glue, and carbonise the remainder for charcoal. The latter procedure gives a lower yield of tar and ammoniacal products. It has, however, been urged that the "char" yielded by this method is much inferior to that produced by carbonising the bones direct, though no sufficient evidence has been furnished to support this objection. On the other hand, tests made of the decolorising power, also of the percentage of carbon, and the specific gravity, prove the quality to be fully equal to that of a "direct" made charcoal. Whether the bone has been partly degelatinised or retains the whole of the organic matter makes no difference in the process of manufacture. When a bone is burnt or carbonised out of contact with air, it undergoes a great change, losing 38 to 40 per

cent. of its weight, emitting empyreumatic, tarry, and ammoniacal vapours, and leaving a black porous mass, retaining the shape of the original bone. This mass, when milled, forms the granular body called "char". The products of distillation are classified into—

- (1) Ammoniacal liquor.
 -) Tar.
 -) Illuminating and other gases.
 -) Char.

The yield varies according to the quality of the bones burnt, and whether they have previously undergone a partial degelatinisation. Assuming an average good quality of bones, 100 tons would yield—

Char	61 tons.
Ammoniacal liquor	13 "
Tar	6 "
Illuminating and other gases . .	20 "

The ammoniacal liquor contains carbonate, hydrate, sulphide, chloride, and sulpho-cyanide of ammonia. The tar, on further distillation, yields bone pitch and oil, and from the latter have been obtained by fractionation pyridin, lutiden, aniline, phenol, and other complex bases, etc., which are up to the present not of great commercial value, however interesting they may be from a scientific point of view.

The formation of these products is the result of a very complicated series of chemical changes in the retort. Bone, as previously explained, is an intimate mixture of organic with mineral matter, in which phosphate of lime largely predominates. The mineral portion undergoes no change at the red heat of the furnace, excepting the reduction of the small quantity of sulphate of lime present to sulphide. On the other hand, the organic matter is profoundly modified—the hydrogen, oxygen, carbon, and nitrogen, of which it is composed, rearranging themselves to form other combinations.

Part of the carbon remains with the mineral matter and forms the char, and to the presence of this fixed carbon in a certain proportion the char owes its valuable decolorising power. Another portion of the carbon goes to form the various hydrocarbons contained in the illuminating gases. A further portion is used in the formation of the oxides of carbon (CO_2 and CO); and lastly, a small portion unites with an equivalent of nitrogen to form the cyanogen present.

The whole of the nitrogen, except the small part which goes to form cyanogen, appears, in the first instance, as gaseous ammonia.

As the gases leave the retort, their temperature falls considerably, allowing a further grouping to take place. The whole of the carbonic acid (CO_2) unites with its equivalent of ammonia, forming carbonate of ammonia which is the principal ammoniacal compound in the liquor. The cyanogen and sulphuretted hydrogen, take up another portion of the gaseous ammonia, forming sulphide and cyanide of ammonium, and these two again unite, forming sulpho-cyanide of ammonium. The free sulphide of ammonia left remains in that form, and finally the excess of ammonia formed by the union of ammonia with the moisture of the bone appears as hydrate.

These changes are somewhat similar to those taking place in the destructive distillation of coal. But in the carbonisation of coal and bone, although practically carried on in the same way, very different ends are sought for. The gas-maker's primary object is the production of a rich illuminating gas—the coke, tar, and ammoniacal liquor being of secondary importance; on the other hand, the char-maker regards the contents of the retort as the more important—the illuminating gases, also the tar and ammoniacal liquor, being simply bye-products.

For the production of char the bones are carbonised in a series of retorts placed horizontally in a furnace, and heated

by means of a fire beneath. They are made of iron, with one end closed, each being 12 feet long, and in shape similar to the letter α . At the open end is fixed the frame or mouthpiece which carries the door swung on a hinge. The door has a slight projecting rim some two inches wide, which, with the surface of the frame, are ground perfectly true; so that on closing the joint can be made perfectly gastight by a lever arrangement. Fixed to the frame on the upper surface is the "up-take" pipe leading to the hydraulic main. Five retorts are generally fitted into each furnace, and the setting is so arranged that, by the aid of dampers and pigeon-holes, the flame may be made to sweep equally round each retort, so that each shall receive its full complement of heat. The spent heat finally passes to an underground flue connected with the chimney. The furnaces are lined internally with fire-brick, and have an outer 14-inch red brick wall, the whole being bound by 1-inch tie-rods.

Each furnace, with its five retorts, is called a bench. The hydraulic main running along the top of the furnaces plays an important part. It not only acts as a receiver for all the volatile products of distillation, but it performs the duty of a stop-valve to each retort, effectually closing it against any return of the gases during drawing and charging. This is carried out by the dip-pipe connected with each "up-take" from the retorts dipping below a layer of ammoniacal liquor and tar which is kept at a certain level in the main. The gases are forced through by the pressure, the liquor acting as a barrier, thus preventing their return.

Fig. 5 is a cross-section of a retort bench.

<i>A, A,</i> are the retorts.	<i>C,</i> up-take pipe.
<i>B,</i> fire grate.	<i>D,</i> hydraulic main.
<i>E,</i> bridge pipe.	<i>F,</i> dipping pipe.

In working five benches the labour is apportioned amongst four men, with the aid of a woman, the latter trimming the

bones when brought to the charging floor; each bench takes twelve hours to burn a charge, and they are drawn in rotation. When ready for withdrawal, the door of the retort is slightly loosened by turning the lever, the escaping gases are burnt at the mouth of the retort and in a few minutes the

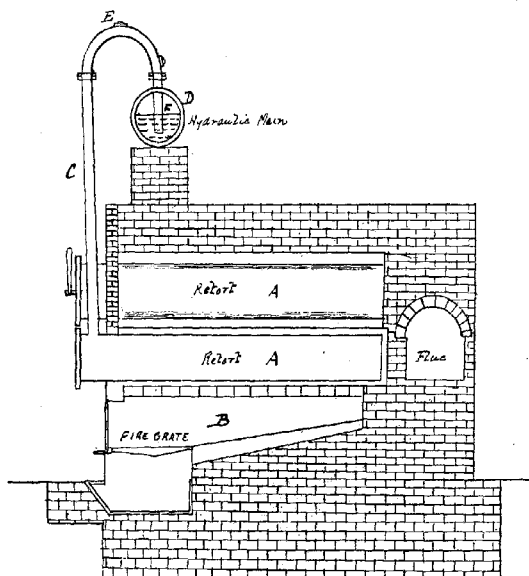


FIG. 5.—Bench of Retorts for Char-making.

internal pressure is destroyed, allowing the door to be opened with safety. The red-hot char is rapidly withdrawn to the "canister" placed ready to receive it, covered, and the "canister" is then rolled to the cooling shed of the mill. Here the lid is luted down with a paste of char dust and water, making an airtight joint, and the char is then cooled for twenty-four to thirty hours. Meanwhile the other retorts

are being emptied in rotation, until the bench is completed. Whilst still red-hot, any unnecessary exposure coats the char with a white ash, which lowers its subsequent value after milling. Each retort is closed on drawing the charge, only being reopened to receive a fresh charge; by this means little or no loss of heat occurs between withdrawing and charging. The work is continuous, with double shifts, until a stoppage for repairs becomes necessary.

A bone, when well burnt, is of a deep black colour, and has a metallic ring when struck. On incineration, in contact with air, usually a white ash is left, but it is sometimes tinged a yellowish brown, owing to a trace of oxide of iron being present. The space occupied by a ton of good quality charcoal equals about 50 cubic feet.

The chars found in commerce show great variation in quality, due to irregularities in the methods of manufacture. The following analyses illustrate this difference:—

	No. 1 Good Char.	No. 2 Bad Char.
Nitrogenised carbon	10.76	6.83
Phosphate of lime	73.50	70.39
Phosphate of magnesia	6.08	8.47
Calcium carbonate	8.69	10.92
Calcium sulphate . . . .	.05	.78
Calcium sulphide . . . .	.03	.46
Ferric oxide . . . .	.16	.63
Alkaline salts . . . .	.44	.49
Silica (sand) . . . .	.29	1.03
	<hr/> 100.00	<hr/> 100.00

A good char should contain approximately 10 to 11 per cent. of carbon, and the ferric oxide ought not to exceed .25 per cent. It is sold on a basis of 8 per cent. of moisture, and the dust it contains is regulated by the grade of char made.

The char, after cooling, is emptied from the canisters, and watered, it is then ready for the mill, a view of which is seen in the longitudinal section of Fig. 6. The char enters the mill at *A*, an oscillating wooden trough, 6 feet long by 15 inches wide by 7 inches deep, called the "feed". The trough is fitted with five sheet-iron cross-pieces, running the full width, and equally placed, thus dividing it into six divisions. The char is delivered gradually into the first division, and the oscillating movement carries it over the first iron cross-piece into the next division, and so on until the last is reached, whence it falls into the cutting-machine *B*.

The bones, however carefully sorted for the grease extractors, sometimes carry with them small pieces of iron, brick, etc., which, on passing to the very fine wire-cloth used in the mill, would do considerable damage. To guard against this the oscillating arrangement is carried out, the lighter char is shaken over the iron cross-pieces, leaving behind, mainly in the first and second divisions, any heavy metal or other substance. Leaving the "feed," the char falls into a receiver, and, passing between two revolving toothed wheels, is cut into small portions about one inch long, which fall into the "boot" of the elevator *CC*; this carries it to the revolving cylinder or riddle *D*, covered with a No. 7 cloth, which separates the fine from the coarse char, the fine passing down through the wooden "shute" *E* to the revolving cutters at *F*, the coarse char, leaving the riddles, falls down the "shute" *G* and enters the revolving cutters *H*. After a further cutting or grinding, both chars unite in the elevator "boot" *I*, and are lifted to the "shute" *J*, which passes it on to the revolving riddles *K*. These riddles, covered with a 60-mesh cloth, are used for the purpose of sifting the char. A large proportion of dust in the char is thus separated, which, on falling to the bottom of the mill through the "shute" *L*, is bagged at *M*. The clean char then passes on

to another system of revolving riddles covered with wire-cloth, to suit the grade of char to be made, and is finally

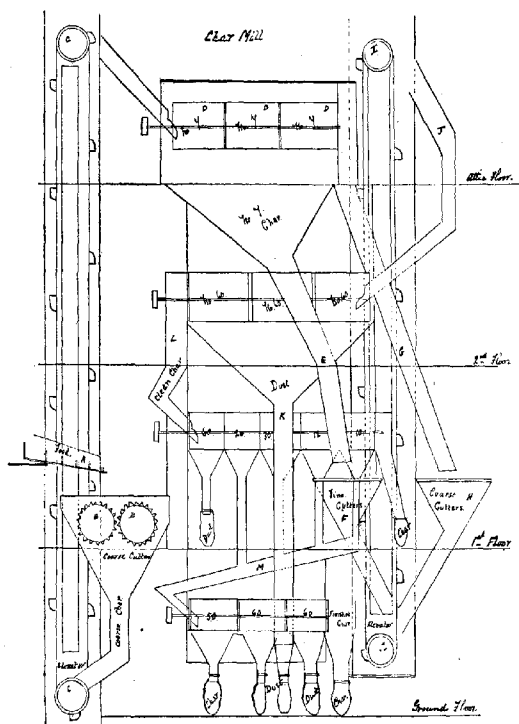


FIG. 6.—Plant for Grading Bone Black.

bagged at N. Passing through the cloths of a coarser mesh than 60 is also char of another grist, which is again cleansed of any dust by passage through the 60-mesh riddles OO, and lastly bagged for finished char. The cloths at N are con-

tinually changed to suit the grade required, and also extra rounds of 50^s or 60^s mesh are put on to suit the dust limit guaranteed in the grist of char being made. The taking off and replacing of the various wire-cloths is a source of loss, the cloths becoming torn and otherwise damaged. Some manufacturers remedy this by gristing four to five thousand bags of each quality likely to be in demand before changing the cloths. The following are some of the chars made, with their mechanical composition or grist:—

Grade 30/60.			Grade 16/60.					
Size 30	.	19.13	Size 16	.	5.72			
„ 40	.	26.19	„ 18	.	13.03			
„ 50	.	33.49	„ 20	.	23.84			
„ 60	.	15.86	„ 30	.	30.16			
„ Dust	.	5.33	„ 40	.	14.25			
		<u>100.00</u>	„ 50	.	8.16			
			„ 60	.	3.09			
			„ Dust	.	1.75			
					<u>100.00</u>			
Grade 10/60.			Grade 12/20.			Grade 20/30.		
Size 10	.	7.62	Size 12	.	4.15	Size 20	.	1.16
„ 20	.	37.50	„ 20	.	83.89	„ 30	.	67.11
„ 30	.	17.42	„ 30	.	11.51	„ 40	.	25.12
„ 40	.	16.39	„ 40	.	.72	„ 50	.	3.39
„ 50	.	12.14	„ 50	.	.31	„ 60	.	2.15
„ 60	.	6.82	„ 60	.	.24	„ Dust	.	1.07
„ Dust	.	2.11	„ Dust	.	.18			<u>100.00</u>
		<u>100.00</u>			<u>100.00</u>			

In a high-grade char the percentage passing through size 40 is limited to 2 per cent. In the grist of the 12/20 char, as seen above, this limit amounts only to 1.45 per cent., whilst in the common grade char, 30/60, it is 54.68 per cent.; 12/20 char is chiefly used in Japanese refineries. About 15 per cent. of the weight of the burnt bones from the retorts

are reduced to a dust in milling. Each grade of char takes up a portion, and the remainder is bagged. Possessing little value as a decoloriser, the manufacturer converts it into superphosphates, or realises a better price by grinding it for ivory black. For either export or home use the char is packed in 2-cwt. bags.

In the hands of the sugar refiner the life of a char may be placed at two years. During this time it is many times reburnt to destroy the organic colouring matter and other impurities absorbed during the passage through it of light or dark-coloured sugar syrups. The destruction of this organic matter increases the fixed carbon, the char becoming more dense, and less porous, ultimately its decolorising power is reduced to a minimum. The char then becomes what is technically termed "spent," and is generally bought by the char-maker for conversion in the manure house into superphosphates.

A sample of "spent" char gave on analysis—

Carbon	21.62 per cent.
Tribasic phosphate of lime	73.65 „

The tar and ammoniacal vapours leaving the hydraulic main are passed through a series of vertical pipes, termed "the condenser". The size, height, and number of these pipes depend on the quantity of gas that has to be cooled in a given time. Generally 70 square feet of pipe surface is allowed for the cooling of 1000 cubic feet of gas per hour. The gases alternately ascend and descend the pipes until their temperature is reduced to about 80° or 85° F.; this lowering of the temperature condenses the minute particles of tar with the ammoniacal gases. At the bottom, formed in the brickwork on which the pipes rest, are a number of wells, each serving two pipes, into which the condensed tar and liquor falls. These are drained into a main pipe carrying the whole of the condensed products to the main separating

tank. Owing to the difference in gravity, the tar rises to the surface and is floated away through a discharge pipe to the tar well, while the ammoniacal liquor is pumped to the still or boiler for subsequent distillation. In order that the gases may traverse the condensers with a steady and regular flow, and at the same time to relieve any great pressure in the retorts and hydraulic main, thus freeing the former from any heavy deposit of carbon, an apparatus called "the exhaustor" is connected with the outlet condenser pipe. In some works a scrubber or washer is used to wash the gases forced from the exhaustor, the object being to recover any uncondensed tar and ammonia. The scrubber is built of curved steel plates bolted together; it is about 20 feet in height, with a width of 6 feet, and is supported by a structure of brickwork. Inside are a series of perforated trays, placed 14 inches apart, carrying a layer of coke, broken into small pieces; at the top a rose pipe is fixed, which throws a spray of water evenly over the surface of the first layer of coke, and thence, trickling down from layer to layer, it meets with the ascending gases, dissolves out the tar and ammonia, leaving the uncondensable portion to pass out at the exit pipe placed at the top. The dissolved products leave the scrubber by the exit at the bottom, and are conveyed to the main separating tank.

The uncondensable gases still require a further purification to remove the carbonic acid and any volatile sulphur compounds. For this purpose they are passed through perforated trays holding layers of slaked lime some three inches deep, the trays being enclosed in boxes with movable tops, and built of $\frac{3}{8}$ -inch steel plates. They are generally constructed 10 feet square, with a depth of 4 feet. The gases pass in at the bottom and ascend through the various layers of lime, which absorb the impurities, finally passing out at the top direct to the gasometer.

The volume of gas formed is considerable, and in its use

for lighting the works, or for motive or heating power, it plays a very important part in the successful working of a concern. The bones passing into the retort contain about 6 per cent. of nitrogen. A portion of this goes to form the complex organic substances of the tar; another portion is contained in the illuminating gases as free nitrogen and cyanogen; a further quantity is lost in actual working; and the remainder goes to produce the various ammonia compounds forming the ammoniacal liquor.

In the manufacture of cyanide of potash nitrogen forms one of the chief factors, therefore any cheap source for providing it in an available form for this purpose would be welcomed. Many attempts have been made to convert the nitrogen of the atmosphere directly into cyanides, but with indifferent results. Better success has attended the use of high strength ammonia as worked by Beilby's process. There is, however, ample room for further improvement. Cyanide of potash at present commands about £112 per ton on a 98 per cent. basis, the demand increases as the old chlorination method of extracting gold dies out and new goldfields are discovered. If the char manufacturer had only some method of converting the store of nitrogen in the ammoniacal liquor into cyanide, or by some simple means could intercept the gases coming from the retorts, take away the nitrogen and convert it into cyanide instead of sulphate of ammonia, the gain to him would be considerable. Supposing, for instance, he could use only 3 per cent. of the nitrogen for this purpose, he would obtain on the 100 tons of bones calcined 11·6, say 11½ tons of cyanide of potash, which at £112 per ton would have a value of £1302. When this amount of nitrogen is converted into sulphate of ammonia the tonnage obtained is 23·57, say 23½ tons, at £11 per ton, which only realises £258 10s.

Possibly, as chemical research in this direction progresses, means may be devised of using the whole, or greater part of the

nitrogen for the more valuable process of making cyanide. As it is, the char-maker is of necessity confined to the manufacture of sulphate of ammonia, which realises at the best but a moderate price, at the same time saving only a part of the nitrogen which the bone originally contained. The still receiving the ammoniacal liquor has a capacity of 6000 to 7000 gallons. It is built of boiler plate, dished at both ends, and has a dome or still-head, to which is bolted the 6-inch conveying pipe. Along the bottom steam pipes are arranged for boiling purposes. Midway between the still and the "sulphate box" is a cylinder, fixed vertically on wooden supports. To the bottom is bolted on the conveyer pipe leading from the still, while the outlet pipe is fixed with a flange to the top, and then continues to the "sulphate box". This cylinder is fitted with the object of retaining any liquor which may froth over during the boiling, and also at the same time to condense a considerable portion of the watery vapours; both of which pass back down the inclined conveyer pipe to the still. The "sulphate box" is a circular iron vessel lead-lined, covered with a hood to carry off any obnoxious gases, and fitted with a sliding door, through which the workman watches the operation, and also "fishes" out the finished sulphate. Close at hand, but on a higher level, is placed the acid storage vat, containing brown oil of vitriol, which is run by a lead pipe to the "sulphate box," the stream being controlled by a "cock" placed within easy reach of the workman. The "sulphate box" is half filled with strong acid, so as to cover the lead dipping pipe; the gases coming from the cylinder bubble through the acid which instantly unites with the ammonia, the union being accompanied with considerable ebullition. When the saturation point is reached, the sulphate separates out in fine particles or crystals, falling to the bottom of the box, and at intervals is "fished" out by a ladle and thrown on an inclined table to drain. From time to

time the workman observes the odour of the issuing vapours, and if the pungent smell of ammonia should be detected, further addition of acid is made to neutralise it.

A still requires some fourteen hours to work off the ammonia, and the residual liquor will have a strength of about $\frac{1}{4}^{\circ}$ Twaddell.

The sulphate of ammonia produced is grey in colour, and contains on an average 95 per cent. of pure sulphate. The yield is about eight per cent. on the quantity of bones carbonised.

The value of the tar rests solely on the amount of residual pitch recovered when it is distilled, the yield averaging 14 lbs. for every ton of bones "retorted". It is used mainly for the manufacture of black varnishes, Brunswick black, etc. The volatile products yield by condensation an oily liquid, to which the term "bone oil" is given. Up to the present time no practical use has been found for this, other than that of spraying into the fire-grates of the steam boilers, and thus lessening the consumption of fuel.

MARROW BONES.

Part of the raw material delivered at the works consists of the thigh and leg bones, termed "marrows" or "knuckles". These realise a much higher price, and are treated separately from the common bones. The first operation consists in sawing off the ends, leaving bare the core; the ends being passed on to the extraction house for benzene treatment. The sawn bones are conveyed to a large vat, here they are covered with water, in which a little salt is dissolved, and they are allowed to steep for three days. The salt assists in the removal of any blood contained in the bones. After steeping, they are removed to the boiling vat, again covered with water, which, by the aid of a steam coil, is brought to a simmer, but not higher, for six hours. Excess of boiling renders the

bone "chalky" and "soft," and its value is thus considerably lowered to the button-maker. During this simmering the fat rises to the surface of the water and is skimmed off into a cooler. When the steam is turned off, the water is gradually cooled to 130° F., the bones being then removed; each individual bone is "scrubbed," to detach any soft "mealy" matter or dirt, this work being done by a number of girls. They are now wheeled to an open shed, spread in single layers on racks, in which they are allowed to dry in a strong current of air, and then stacked for use. The average yield of marrow fat is about nine per cent., a sample of which gave on analysis the following results:—

Impurities—Water	1.46 per cent.
Organic matter (other than fat)	0.02 "
Mineral matter (ash)	0.43 "
The clean fat consisted of—	
Neutral fat	47.07 per cent.
Glycerine (1.24 sp. gr.)	5.28 "
Free fatty acids	52.93 "
Non-saponifiable matter	None.

Marrow fat is much lighter in colour than benzene extracted bone fat, and consequently commands a better price. It is used for soap-making, also for expressing the fat oil which is used as an adulterant in neat's-foot and other high-class oils, and for other purposes. The following is a pressing of good marrow fat:—

Temperature of pressing, 55° F.

Marrow fat weighed 10 cwt. 3 qrs. 6 lb. and yielded—

Stearine	6 cwt. 0 qrs. 16 lb.
Fat oil, 57 $\frac{2}{3}$ gallons, weighing	4 cwt. 2 qrs. 15 lb.

10 cwt. 3 qrs. 3 lb.

Temperature of atmosphere and oil, 55° F.

Pressure exerted = 150 tons.

When the bone is not to be used subsequently for

button-making, a much greater yield of fat is obtained by the following method : Take the marrows, saw off the ends, and wash well with water until the visible blood is washed away, then place in a digester, half fill with water, previously adding 5 to 7 lbs. of salt for every 5 cwts. of bones ; and digest for eight hours, with a steam pressure of 40 lbs. When digested, allow the liquid contents to run off into a receiver ; the fine fat will float on the liquor containing the glue and other bodies removed, and after skimming is brought into the market under the name of "Premier Juice".

A few firms carry on in this country the manufacture of buttons, etc., but this industry is mainly centred in France and Germany, to which countries are shipped large quantities of prepared marrow bones. Not only do they make buttons, spoons, paper-knives, and many fancy articles from bone, but they convert the residual cuttings, rings, etc., into high-class gelatine, whilst the fine meal from the drills forms an additional source of profit, being used as an admixture in the food of poultry, dogs, etc.

CHAPTER II.

GLUE.

THE art of glue-making is one of the most important processes of the bone works. Glue is an impure gelatine, and has a similar composition to the cartilage from which it is obtained by boiling. The colour of glue varies according to the manufacturer's requirements. Glue of good quality is practically free from smell, is unaffected by the atmosphere, and has great adhesive power. When immersed in cold water for twenty-four hours it remains quite insoluble, while the original weight increases from four to six times by the absorption of water. In hot water glue dissolves completely, giving a clear liquor which jellies in a few hours to a firm mass. On incineration a slight white ash is left, consisting chiefly of phosphate of lime. Glue is perfectly insoluble in ether and all fatty oils. With sulphuric acid a rapid change takes place, and glycoll, otherwise termed sugar of gelatine, together with leucine is formed; whilst on heating with nitric acid oxalic acid is produced. According to the nature of the materials from which they are obtained, glues may be classified as bone or hide glues. Chemically the difference between the two rests on the amount of glutin each contains; physically, the adhesive power and elasticity of hide are greater than those of bone glue.

Of the two nitrogenous substances, glutin and chondrin, that form the material we know as glue, glutin has a much greater adhesive power than chondrin: in all hide glues this

substance predominates, being derived from hide and osseous parts, consequently they are the stronger. Chondrin is derived from the cartilage of the ribs, shoulder-blades, etc., and is predominant in bone glue.

In a works dealing mainly with bones the production of skin glue is but a subsidiary branch; the liquors being principally used to strengthen and impart viscosity to certain classes of bone glue made. The skins are firstly "limed" in a thin lime-water for several days, the time occupied varying according to the appearance of the skins; if soft and bluish, the "liming" is continued. On the other hand, too much steeping diminishes the yield of glue, which may, however, be of excellent quality. The skins should be "firm" and free from any greasy feel before they are taken out of the lime vat. The "liming" effects the solution of the blood and flesh of the skins, and at the same time saponifies or emulsifies the fatty matter. After this operation the skins are now thoroughly washed in a perforated iron cylinder, which is placed horizontally and revolves on its own axis. The cylinder has a diameter of 6 feet, and a length of 4 feet, it is open at both ends, around the inside being fixed a number of wooden baffle plates 6 inches broad, which, as the cylinder revolves, carry the skins with them, ultimately allowing them to fall to the bottom; during this operation they are submitted to a strong stream of water. In the cylinder also is arranged an iron plate, supported by stays from the outside. While the washing is in operation the plate is turned vertically; but on completion of the washing this is brought to a horizontal position, forming a table on which the skins fall, and from which they are removed to a hand press to squeeze out the water.

The effluent water from the washer is heavily charged with lime, the alkalinity at times being as much as 192 grains per gallon. In addition the water also contains a considerable

quantity of organic matter together with lime soaps formed during the "liming" process, and which, if run direct into a stream, would certainly lead to considerable risk of pollution. To remedy this a large settling tank, built of brick and lined inside with cement, is provided, the size being regulated according to the quantity of effluent produced daily; into this the day's effluent is run, and on the stoppage of the washer, a mixture formed by dissolving two parts of ferrous sulphate and one part of alum in a little hot water, is added. After stirring, the whole is allowed to settle for eight to ten hours, when the water becomes quite clear, and with safety can be run into a stream. The thick sludge is removed by pumping, dried by any waste heat in the works, and then used in the manure shed. The cost of treatment is about 11d. per 7000 gallons of effluent.

The skins from the press are now taken to the glue-boiler, which is an open vessel, 8 feet diameter at the top, and 7 feet deep, provided with a perforated false bottom, through the centre of which passes a 2-inch open pipe, one end dipping below a layer of water at the bottom, the other projecting about half the height of the boiler, this end being covered with a perforated hood to spray the liquor through the mass. The skins are placed on the false bottom, and the added water at the bottom of the boiler brought to the boil by means of a steam pipe. The steam, not being able to escape quickly through the dense mass of skins above, exerts a pressure on the water, forcing it through the pipe, by which it is sprayed through the mass, and ultimately it works its way to the bottom of the boiler, to be forced up again. This continual circulation of the hot liquor rapidly dissolves the gelatinous matter, and when a strength of 18 per cent. of dry glue is reached, the first run is made to the evaporating pan, the liquor passing first through a filter of fine shavings, to remove any suspended matter. Fresh

water is added to the contents of the boiler, and the boiling renewed. Three extractions are usually made, the last being used for size. The evaporating pan used is 6 feet square and 3 feet deep, arranged with a coil of piping, the liquors being evaporated down to a strength of 32 to 34 per cent. of dry glue, subsequently being used as an admixture to certain bone glue liquors, or it may be jellied in coolers, cut and dried in the usual way. Some glue boilers add a little alum to the liquors before concentration, to precipitate any lime and remove turbidity; the liquors thus treated however require to be filtered anew before evaporation; on the other hand many boilers do not find this necessary.

In works where the bones are subjected to the benzene process, they usually undergo no other treatment after being cleansed, but are sent direct to the glue-extractors. Sometimes, however, an exception is made to this procedure, the boiler immersing a charge in a bath of muriatic acid, about 1° Twaddell strength, for twenty-four hours, and after washing, fills his extractor. He assumes that such treatment improves the quality of the glue; however, any slight gain here is counterbalanced by the labour and time expended, the loss of phosphate of lime dissolved, and the value of the acid used.

The system of glue-boiling varies with different firms; some adopt the water system, and others the direct steam process. In the former the extractors are small, holding about 3 tons each, generally worked in couples, water and steam being made to play alternately through each extractor. For this a plentiful supply of hot water is required, necessitating a special boiler for feed purposes. The liquors yielded are large in bulk, and vary considerably as regards their strength, the average being about 10 per cent. of dry glue. The degelatinised bones withdrawn from the extractors are very wet, and therefore give an inferior bone meal when dried and ground.

The following analyses are of four samples of degelatinised bones, drawn at different periods, and give the percentage of nitrogen, unrecovered as glue, by this process:—

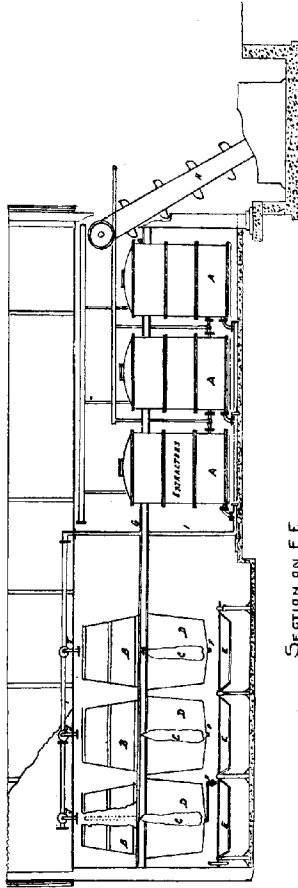
	(1)	(2)	(3)	(4)
Nitrogen in degelatinised bones .	1.29%	1.18%	1.36%	1.24%
Equal in glue to .	7%	6.40%	7.35%	6.73%

The direct steam method may be considered a more economical method of extraction. Less room is required for the plant, and it is more easily worked. The liquors are less bulky, and have a higher strength, averaging 20 per cent. of dry glue, which is a very important advantage in the after evaporation. In addition the bones are drier, and the bone meal is of better quality.

Of four samples of bones degelatinised by the steam method, and drawn at different times, the percentage of nitrogen was as follows:—

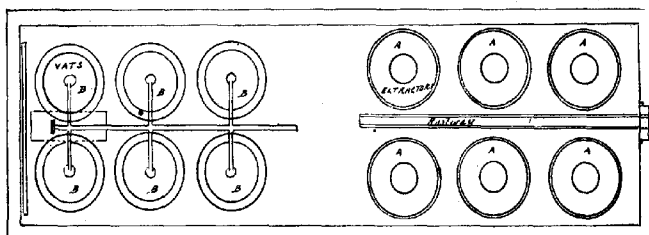
	(1)	(2)	(3)	(4)
Nitrogen in degelatinised bones .	.93%	.87%	1.13%	1.05%
Equal in glue to .	5.04%	4.72%	6.13%	5.70%

The percentage of nitrogen, practically unrecoverable in the form of glue, therefore is 1 per cent. In Fig. 7 is shown a section of a glue-boiling and clarifying house, with plan of clarifying vats, filters, and evaporating troughs. The whole of the operations are carried on within one building, which is provided with an upper floor, supporting the vats, as shown in the first floor plan (Fig. 8). This floor also carries a small railway, running the length of the extractors *A*, so that the cleansed bones, as brought up by the elevator *H*, may be rapidly discharged into them. In the plan is shown an installation of six extractors, built of mild steel plates well riveted together, and holding 4 tons each. According to the amount of size made, either one or two are

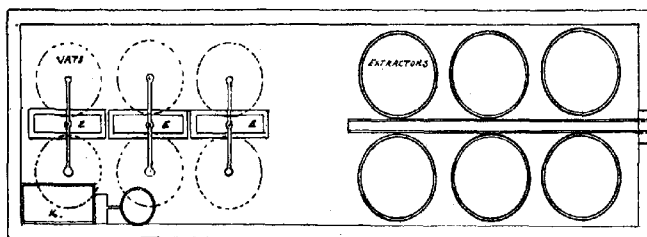


SECTION ON E F.
FIG. 7.—Glue Boiling Plant.

used for that purpose solely, the rest being exclusively employed for glue. On the ground floor is placed a small railway on which trucks run for the rapid removal of the treated bones. The liquor from all the extractors is discharged into one main pipe which feeds, by means of branches, the different vats *B, B, B*. The latter are built of wood, 1 $\frac{1}{4}$ inches



Plan, Showing Arrangement of Clarifying Vats. 1st Floor.



Plan Showing Arrangement of Extractors. Ground Floor.

FIG. 8.—Glue Boiling Plant. Plan.

thick, and stoutly bound with iron hoops. Each vat is fitted with a copper steam coil, the tube being 2 inches in diameter, and is also provided with an upright perforated copper pipe, 2 $\frac{1}{2}$ inches diameter, passing through the bottom of the vat, to which is fixed a cock to shut off or regulate the flow of the liquor after the bleaching and clarifying is finished. Under-

neath are placed the bag filters *C, C, C*, made of stout calico and having a length of $7\frac{1}{2}$ feet, the filters being enclosed in the boxes *D, D, D*, to prevent any loss from the liquor spurting out. On the ground floor are placed the three evaporating troughs *E, E, E*, each one evaporating the liquor from two vats. The liquors leaving the clarifying vats have a strength of about 20 per cent. of dry glue, and are evaporated until they have a strength of 32 per cent. in winter and 35 per cent. in summer. For this purpose spiral evaporators are used, forming a ready and economical means of evaporation. The evaporator consists of a spiral steam coil, made of copper, 2 inches diameter, revolving on a central shaft; the lower half of the coil is covered with the glue liquor in the trough, the upper half carries a thin film of glue liquor with it. The shaft rests on two plumber-blocks, one receiving the steam, and the other discharging the spent steam and condensed water. The shaft is hollow as far as the first coil, from whence the steam is conveyed to the spiral. From the last coil to the end of the plumber-block the shaft is also hollow, and in that portion resting on the block two openings are made. In the inside of the plumber-block, two corresponding openings are made to the outside, each forming a covered channel; therefore, as the shaft revolves, all the holes directly face each other at intervals, which allows any condensed water in the coils to be blown through. From twenty-five to twenty-eight coils are the most usual number in each spiral. The glue liquors are fed into the trough at one end, where they have a temperature of 75° C., the temperature of the evaporated liquor at the other end of the trough being 85° C. In the slow passage through the trough, the liquors receiving the heat of the revolving coils become raised in strength from 20 per cent. to 32 per cent. of dry glue, at which point they are ready for jellying.

On this floor also is placed the sulphurous acid generator,

a longitudinal section of which may be seen in Fig. 9, comprising an air-compressing engine *A*, throwing a current of air into the iron cylinder *B*, in which is placed a tray containing burning sulphur. The sulphur burns to sulphurous acid gas by the aid of the oxygen of the air blown in, and is then passed into the lead-lined wooden vessel *C*, which acts as a washer. On bubbling through the water, it is conveyed by the pipe *F* to the clarifying vats. The method of bleach-

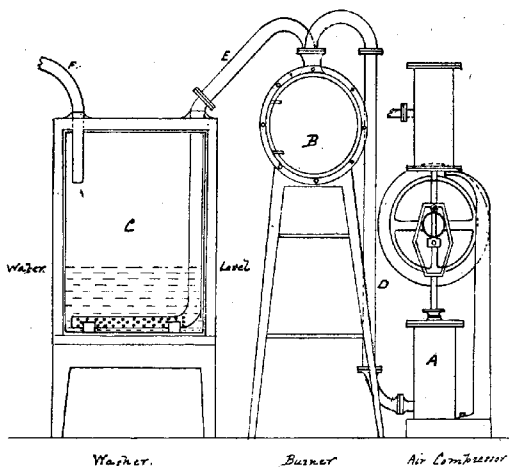


FIG. 9.—Sulphurous Acid Generator.

ing with the gas is more economical than the use of a solution of sulphurous acid, and it may also be regulated so that any shade of colour can be obtained.

In each extractor, not shown in the section, a "vomit" pipe, 3 inches in diameter, is placed in the centre, and supported on the bottom by three stools. The pipe runs through the false bottom to within a foot of the top of the extractor, being fitted with a hood for spraying equally the ejected

liquor over the surface of the bones. At the bottom a 1-inch steam injector pipe is led just inside the "vomit," the end being closed with a column of water 9 inches high. The successful working of the "vomit" pipe depends on the unequal pressure above and below the false bottom, it serves a useful purpose in washing down the glue exuded from the bones. In working a charge of bones, the initial steam-pressure should not be above one atmosphere (15 lb.), which is gradually reduced to 5 lb. This lowering of the pressure allows the glue formed within the bone to come to the surface, from which it is removed by the spray. To each extractor is fitted a pet cock, which enables a sample to be withdrawn at any time for inspection. A charge usually takes about eighteen hours, and the liquors are drawn off at intervals of six hours.

On discharging from the extractors, the liquors are led to the clarifiers, where they are treated with the requisite quantity of alum, previously dissolved in a little of the glue liquor, and kept by the steam coil simmering for half an hour; the temperature is then lowered to about 80° C., and the sulphurous acid gas allowed to bubble through until the desired shade is obtained, small samples being drawn from time to time for inspection. On completion, the under-valve is opened, and the liquor allowed to run into the bag filters for filtration, and from thence to the evaporating troughs.

In the clarification of glues many attempts have been made to replace alum as a clarifying agent by other materials such as phosphate of soda, oxalic acid, blood, sub-acetate of lead, infusion of bark, etc., but none of these have proved superior for the purpose. Alum, used in excess, is undoubtedly injurious to glue, but the proportion necessary for clarification is so small that it cannot have a marked action.

The concentrated glue liquor leaving the evaporators is jellied by running it into sheet-iron troughs, called coolers,

and allowing it to stand in a cool place for twenty-four hours, or, if the glue made is what is called a cast-glue, it is run on to glass coolers, to the required thickness, there jellied, and subsequently cut into cakes which are dried. Cut glue has a better appearance than cast-glue, although it may not be a stronger glue.

One of the most difficult operations of the glue-maker is that of drying the glue. The temperature of the air as well as its humidity have to be carefully watched and guarded against. Glue will not bear a higher temperature than 20° C. (78° F.) when in the jellied state, otherwise it will melt and run through the nets. On the other hand, an excessive humidity in the atmosphere retards the drying of the jelly which in a very short time becomes mouldy.

In Fig. 10 is shown the longitudinal and transverse section, and in Fig. 11 the upper and ground floor plans, of a modern drying-house. On the ground floor the whole of the liquors are jellied in coolers, and also cut into cakes by the two cutting machines in the centre. Here a hoist *E* (p. 44) is placed, which carries the cut cakes on "glasses" to the floor above. The upper or drying floor is partitioned off into three divisions, running nearly the length of the building. The two outer divisions form the tunnels proper, and at the end of each is fixed a powerful fan, capable of revolving at high speed, thus drawing the air through the tunnels with considerable velocity. At the opposite end to the fans are fixed a series of 6-inch pipes, heated by waste steam; the air passing between being heated to any desired temperature, but preferably below 78° F. In the centre passage a number of girls are employed in transferring the cut cakes to the nets, which are built up on a carriage running on a small railway. The carriage, with its complement of filled nets, is run to the end of the division, transferred to the lower railway *C*, by which it is carried either to the right or left hand tunnels as

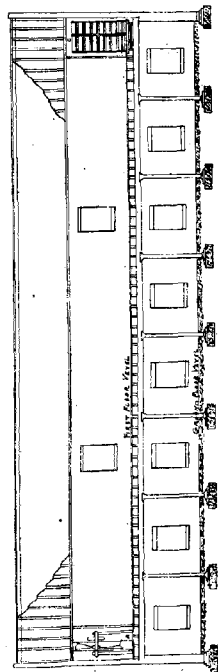
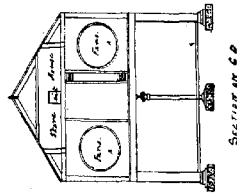
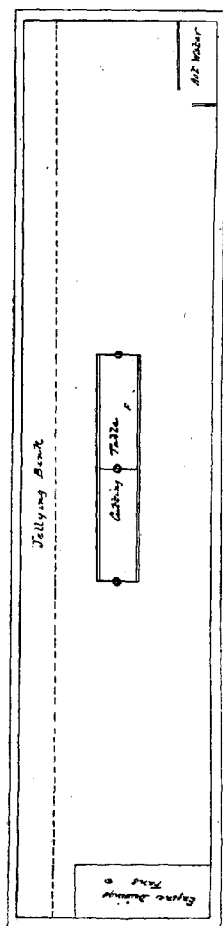
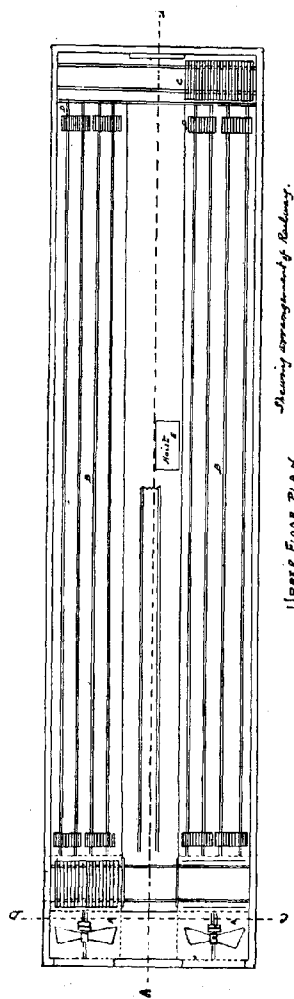


FIG. 10.—(See also p. 44.) Glue Drying Shed.

[See next page for Upper and Ground Floor Plans.]



Glue Drying Shed. Plans.

desired; the glue, when dried on the nets, is run to the other end, and by another lower railway brought to the middle division, being ultimately raised by the hoist to a large store-room (seen in section), where the glue is sorted and bagged. At the end of the store is placed a grinding machine, in which all the off-colour and twisted cakes are ground to a powder to be afterwards sold as powdered glues. The manufacturer, by varying the size of the cakes, their thickness, and colour, makes any number of grades from the same boiling of bones.

The appearance of a glue is no indication of its strength. A glue may be quite clear and bright, and show good shrinkage, yet it may have but medium adhesive power. On the other hand, a dull, heavy-looking glue may have greater strength and be more valuable to the user. A good glue should break sharply, and with a glassy fracture, it should be brittle, hard, and quite transparent. A good practical test for the consumer is to take a portion, dissolve it in eight times its weight of hot water, then allow it to stand for twelve hours. The resulting jelly, if made from a good glue, will be firm and capable of withstanding the pressure of the fingers.

The following should comprise the specification of a good bone glue:—

- (1) The sample should take up at least four times its weight of water, when a known weight is placed in cold water for twenty-four hours.
- (2) The jelly thus formed should be firm, consistent and cohesive.
- (3) The viscosity of a 1 per cent. solution at 18° C. should be at least twenty-nine seconds when 50 c.c. are run through a burette, taking water at twenty-five seconds.
- (4) A jelly of 11 per cent. strength made by dissolving the glue in hot water, and then allowing it to stand for twelve hours, should bear a weight of at least 15

grams (plus the funnel, which weighs 10 grams) at a temperature of 18° C. (shot jelly test).

- (5) The sample should give off no unpleasant smell when dissolved, and the solution should develop no fungus when allowed to stand six days in the cold.
- (6) The sample should not contain more than 20 per cent. of sulphurous acid, or its equivalent of sulphites, or mineral acid.

SIZE.

The demand for some agglutinating material which, while possessing the adhesive properties of a glue, shall be easier to dissolve in water, and obtainable at a much reduced price, has brought into existence a commercial article to which the name "size" has been given. Size is simply glue in its undried condition; in the commoner qualities this is a very impure product. The properties common to glue made from bone or skin are naturally to be found in size made from the same sources. In glue, they are concentrated; in size, the reverse. The proportion of water in the former ranges from 10 to 13 per cent.; while in the latter, a common quality may contain as much as 75 per cent., which thus enables a manufacturer to sell at from £5 to £6 a ton. Many firms who have a good selling connection for size, have not gone to the expense of erecting clarifying plant and drying-house for treating the glue liquors, but prefer to stop the process of glue-making half-way, as it were, marketing the resulting product as size. Others again, with a complete glue plant at hand, convert a portion of their liquors into size, to meet trade demands, the bulk, however, going for the manufacture of glue. Size varies in quality to suit the requirements of different trades. Cardboard box-makers prefer a strong skin size, which is manufactured red or yellow, as preferred. A strong yellow size made from bone is used by calico printers, paper

stainers, wall-paper manufacturers, and in the straw hat and carpet trades. Common size finds various markets as a cheap agglutinant. In the preparation of skin glue the first and second liquors are used for that purpose; the residual mass is then treated with water and steam, which practically exhausts the gelatinous matter. This, third liquor, is used solely for size. During the boiling, samples are taken at intervals, cooled, and the consistency of the jelly noted. The strength is also taken by the glue meter, which registers the percentage. At a strength of 8 to 10 per cent. the liquor is run off, through a filter of fine shavings or cloth, to remove any suspended matter, into a wooden vat fitted with a steam coil, in which it is treated with a moderate charge of sulphurous acid to improve the colour, after which it is evaporated to a strength of 30 to 38 per cent., according to the quality desired, and then run into casks to jelly.

If skin glue is not made, the three runnings are used entirely for size.

In preparing bone size, the bones are first degreased by the naphtha process, then passed through the cleanser direct into the glue boilers, in which they are steamed as in the manufacture of glue; the resulting liquors are forced up to the clarifying vats, partially bleached with a current of sulphurous acid, passing thence through the bag filters to the evaporating troughs, where they are concentrated to 30 or 38 per cent. as required, and then jellied in casks.

The manufacturer with no benzene or glue plant at his disposal, washes the bones in a revolving drum, then, after crushing, they are fed into a boiler, then subjected to alternate currents of steam and water, the latter coming from a spray pipe fixed at the top of the boiler.

The liquors are generally drawn in two portions, having a strength of 14 to 16 per cent. of glue. After separating the fat, which is refined and sold to the soap-maker, the liquors

are run into a large wooden vat (8' x 6' x 4') fitted with a steam coil, in this it is partially bleached with liquid sulphurous acid, and subsequently boiled down to the required strength.

For a common size the bones are crushed, but not washed, they are then fed direct into the boiler and treated as above. The liquors which are not bleached are boiled to a strength of about 25 per cent. of glue.

The composition of the different grades is approximately as follows:—

Common size	25 per cent. glue.
	75 „ water, etc.
Medium size	30 „ glue.
	70 „ water.
Best size	38 „ glue.
	62 „ water.

Concentrated sizes are now prepared by many manufacturers. They are bone sizes and find a ready market in France and Spain, being sold on the Baumé strength at 50° C.

The following may be taken as examples of these:—

No. 1	15° Baumé at 50° C.
	40·5 per cent. glue.
No. 2	20° Baumé at 50° C.
	44·5 per cent. glue.
No. 3	25° Baumé at 50° C.
	49 per cent glue.

Under the name of concentrated sizes are also sold powdered glues of different qualities. They are produced from the off-colour and twisted cakes, sorted out in the warehouse, and ground to a fine condition by passing through a mill. Their value is based on the quality of the cake ground.

As is well known to makers, size rapidly becomes sour and mouldy or even putrescent unless some preservative is

added. For this purpose sulphate of zinc is largely used. Other preservatives, such as those sold under the names of "Salufer," "Preservatine," etc., have also been employed with good effect. The best preservative for size, however, is crystallised carbolic acid, provided that its odour is not objected to. Formalin—that is a 40 per cent. solution of formaldehyde in water—cannot be used for this purpose, as it renders size insoluble in water and incapable of being melted by heat.

CHAPTER III.

GELATINE.

GELATINE may be considered as a pure form of glue. It is quite transparent, has a slight yellowish tint, is very hard and elastic, but brittle if bent too far. When immersed in cold water, it softens and swells, but does not dissolve. Similarly to glue, gelatine has the power of absorbing water on immersion, this absorption, in good qualities, being as high as 8 to 9 times the weight of the gelatine. In hot water it dissolves completely, the solution on standing for twelve hours in a cool place being converted into an almost colourless, transparent, and very firm jelly. This power of gelatinisation is, however, gradually destroyed by long-continued boiling of the solution. Both dilute and strong mineral acids affect gelatine more or less. Weak acids destroy its adhesive power, while the strong acids decompose it, the products of hydrolysis being glycocoll, leucine and other substances.

Concentrated acetic acid, on the other hand, does not destroy the gelatine, but merely dissolves it. One of the most delicate reactions of gelatine is with tannic acid; even when only $\frac{1}{3000}$ th part of the former is present the solution becomes opalescent. The reaction seems to be of a definite nature, the precipitate consisting of 42.74 parts of glutin and 57.26 parts of tannin.

Gelatine, like glue, is derived from hides and skins and also bones. The gelatine resulting from the former is made by a different treatment to that which the bones undergo;

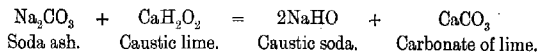
the latter yield the larger proportion of the gelatine which is used, either as a food or for trade purposes.

The manufacture is not carried on in this country to nearly the same extent as in France and Germany, due no doubt in large measure to our variable climate, and also to the fact that with less technical skill the liquors can be readily converted into glue and size, which are more marketable products. The raw materials for gelatine have to be selected with the greatest care and judgment; they must be quite fresh; the skins—preferably those of calves and sheep—being cut into pieces by a machine in which a number of knives are fixed to a revolving shaft, then thoroughly cleansed from any blood by soaking in a brine solution of 3° Twaddell strength, afterwards washing well. The bones used are mainly the ribs and jaws, which are also well washed before using.

The clean waste cuttings and rings from the button factories are also utilised in the manufacture of gelatine.

SKIN GELATINE.

The method of preparing gelatine from skins has changed but little since Nelson introduced his process. The first treatment the cleansed skins are submitted to is the "steeping" process in which caustic soda or milk of lime is employed. In some factories a mixture of caustic (slaked) lime and soda ash is used, in the proportion of 6 lb. of soda ash and 6 lb. of slaked lime to every hundredweight of skins treated; under these conditions the whole of the carbonate of soda (soda ash) is converted into caustic soda by its equivalent of caustic lime, the excess of the latter remaining unaltered. The equation representing this is as follows:—



The steeping is conducted in large wooden vats, each having

a length of 12 feet, width 8 feet, and depth 3 feet, fixed with a slight gradient to the overflow, which is placed at the most convenient corner of the vat and protected by perforated boards. The skins in the vats are nearly covered with water, and then the solution of caustic soda, prepared as above or one of slaked lime mixed in water to a cream, is sprayed equally over the mass, the whole being intimately mixed with long stirring poles. The water is run away and renewed twice during a period of twelve days, the time allowed for the skins to soak. They are now removed to a chamber, in which a moderate increase of heat facilitates the saponification of the fat and the solution of the fleshy matter. The chamber is a brick building, with a cemented floor, on which the skins are spread to a uniform depth of about 6 inches; it is heated by steam pipes running round the building. The temperature being about 70° F. the skins are exposed two or three days, with frequent turning. They are now transferred to the washing machine, which is similar to the one described under "Skin Glue," in which they are washed until the effluent is practically free from soda or lime. The skins then undergo a bleaching operation to whiten them, and thus destroy any injurious colouring matter. For this purpose the washed skins are removed to a number of vats fitted with folding covers, in which they are treated with a solution of sulphurous acid of $\frac{1}{2}$ ° Twaddell strength, for twenty-four hours, each vat being well stirred at intervals to allow the "bleach" to permeate equally through the mass.

In some factories this process is carried out with sulphurous acid gas which is generated in a sulphur burner, and, after washing, passed into a chamber containing the skins. The vats are now drained, then filled up with water, well stirred, and the water run off. This is repeated until the effluent is practically free from any sulphurous smell, then the work of dissolving the gelatine is proceeded with. The

digestion of the skins is carried on in stoutly built circular wooden vats, their size being generally 4 feet 6 inches diameter and 6 feet deep, and into each is fitted a 2½-inch copper steam coil. The vats are provided with double wooden bottoms to distribute the heat. They are arranged on the first floor of the building, the liquors running through a shallow filter of fine copper gauze to the clarifying vats beneath. The skins are raised by an elevator and fed directly into the vats by means of suitably arranged troughs, then covered with water and steam passed through the coils. The temperature, being frequently taken by the thermometer, should never exceed 177° F. (80° C.). During the digestion, any unsaponified fat and dirt comes to the surface in the form of a scum, which is carefully skimmed off from time to time. Samples are also drawn of the liquors, these being cooled, and the appearance and strength of the jelly noted. After five to six hours' heating, the first liquors are run off to the clarifying vats, at a strength of about 17 per cent. of gelatine.

The vats are refilled with water, and a second digestion made, the liquor running to the clarifying vats at a strength of 12 per cent. In the third digestion the temperature is raised a few degrees, to practically exhaust the gelatinous matter, which can either be clarified to form an inferior gelatine or concentrated for size. The spent material is taken to the manure-shed for mixing purposes. The clarifying of the first and second liquors—also, if used for gelatine, the third liquor—is done separately in the clarifying vats. The clearing agent used is alum, which is added in the proportion of ½ per cent., or instead of this a little blood diluted with water; either of these is mixed with a small portion of the hot liquors in a bucket, and then well stirred in the vats. The temperature is raised to 177° F. (80° C.) to coagulate the impurities, then lowered to 149° F. (65° C.), and the

liquors are allowed to stand for two hours. During this time the coagulated matter rises to the surface, and is skimmed off. On leaving the vats the liquors are filtered through fine copper gauze sieves, from which they pass into a receiver, and thence into the vacuum pan.

Gelatinous liquors being peculiarly sensitive to high temperatures, especially with regard to colour, it is found advisable to evaporate them in vacuo; this method being adopted by all continental makers. The three grades of the liquors, after being concentrated to the required strength, are run on to squares of glass, 4' x 4', fixed in a wood framing, to a depth of $\frac{1}{4}$ -inch for cake and $\frac{1}{4}$ -inch for leaf gelatine, these are then placed perfectly level on racks for jellying. In twenty-four hours the jelly is firm, and can easily be cut to the desired size of cake or leaf. A very fine gelatine is produced by cutting the jelly into small pieces, washing these well with cold water, remelting at a temperature of 80° C., and pouring again on the "glasses" for jellying.

The drying is carried out by exposing the cut cakes, placed on nets fixed to a framework of wood, to a rapid current of dry air in the tunnels, as described in the drying of glue.

BONE GELATINE.

The preparation of bone gelatine depends on dissolving out the phosphate of lime by an acid.

The bones for this purpose are carefully picked, and those of a soft and spongy nature selected, owing to the greater percentage of gelatine-forming nitrogen they contain.

After well washing, to remove any extraneous dirt, in the revolving washer, as described under "Skin Glue," they are fed into a machine called a "cracker," in which the revolving arms or cutters break them into pieces about an inch long, this size being most convenient in the after process of dis-

solving. The crushed bones are then carried by a conveyer to a series of large wooden dissolving vats over which the conveyer passes, and thus the stream of bones can be dropped into any of the vats as desired. These are three-fourths filled with bones, and then covered with a solution of hydrochloric acid of 10 per cent. strength. The acid dissolves out the phosphates of lime and magnesia, the carbonate of lime and the oxide of iron forming the osseous structure of the bone, leaving the gelatinous matter intact. The steeping is carried on for four or five days, or until the bones become soft, leathery and semi-transparent. The acid water is now drained off, a supply of fresh water being added and then discharged. This is repeated until the last water is entirely free from acid, which may be known by adding a few drops of silver nitrate; the absence of any white precipitate, soluble in ammonia, indicating its freedom.

The decalcified bones are now bleached in the manner described under "Skin Gelatine," and then conveyed to the boiling vats. (See "Skin Gelatine".) During the action of steam and water the fatty matter floats to the surface, and is skimmed off from time to time. The gelatinous liquor is treated as described, run into glass moulds, jellied, and dried, in a similar way to skin gelatine.

Some gelatine-makers on the Continent have given consideration to the use of bisulphide of carbon as a solvent for the fat in the bones before they are subjected to the acid treatment. The boiling-point of bisulphide being low (i.e. 115° F.) there would not be the same risk of injury to the gelatine as with benzene, which has a boiling-point of 176° F. Then, again, bisulphide leaves no trace of smell in the degreased bones.

These and other considerations have been favourably considered by French makers. There is no doubt that this solvent will play a leading part in the manufacture of gelatine in the early future.

THE TESTING OF GLUES AND GELATINES.

It may be truly said that the best test of a glue is the amount of work it will accomplish. When used as a cement, an inferior quality has poor binding power, besides on dissolving it may emit an offensive odour. The percentage of chondrin also will be relatively high. On the other hand, a strong glue is free from impurities, and possesses high adhesive properties, due to the larger proportion of glutin.

All glues are combinations of two, closely allied but chemically distinct constituents, viz., glutin and chondrin. The former is derived from the skins and osseous parts; the latter is largely found in the cartilage of the ribs, joints, larynx, etc. As glutin has a greater adhesive power than chondrin, it is the aim of the glue-maker to increase the former and reduce the latter as far as practicable. The following is the percentage composition of the two substances.

*	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Gelatine .	50·0	6·6	18·3	25·1
Chondrin .	49·1	7·1	14·4	29·4

Pure dry glutin is a yellowish transparent elastic substance, very hard, and possessing great coherence. It is devoid of smell, and insipid to the taste. Being neutral in its action, it exerts no influence on the most delicate colours. In cold water it is insoluble, but it softens and swells like ordinary glue. In warm water, glutin dissolves completely, and from the aqueous solution it is precipitated by alcohol, tannic acid, mercuric chloride, mercuric nitrate, and mercurous nitrate. The solution, however, is not affected by hydrochloric or acetic acids, alum, acetate or basic acetate of lead, nor sulphate of iron. Chondrin, in the dry state, is a hard, clear, horny substance, with a specific gravity greater than that of water. Like glutin, it softens to a jelly, but is insoluble in cold water; with warm water it is completely soluble.

Chondrin is precipitated from its aqueous solution by hydrochloric, sulphuric, nitric and phosphoric acids, redissolving in an excess of the acid. The organic acids—tartaric, oxalic, citric, lactic, and succinic—precipitate chondrin also, but the precipitate is not redissolved by an excess. Chondrin is distinguished from gluten by being precipitated with alum, acetate and basic acetate of lead, and sulphate of iron, these reagents having no action on aqueous solutions of gluten. The glues of commerce are derived from hides, skins, or other glue-yielding products, or from bone cartilages. The strength of a skin glue is greater than that of a bone glue. The difference between the two kinds may be detected by breathing on the cakes. Skin glue gives no odour; from bone glue a faint characteristic smell is noticed. They should be quite insoluble in cold water, and yet absorb several times their own weight. All good quality glues dissolve at a temperature of 62° to 63° C.

In selecting a glue, many buyers consider only the physical aspects—the shrinkage of the cake, its colour, and, in a rough and ready way, the strength of a jelly made therefrom. These tests are not always a safe guide to the value. A glue may show a good shrinkage, be perfectly clear, glossy, and hard, and yet be found very weak, owing to a low percentage of gluten.

In the laboratory of a glue works, a full testing of each boiling should be carried out, and entered with the number and date, into a book specially kept for this purpose. The tests should include :—

- (1) Moisture.
- (2) Gluten.
- (3) Viscosity.
- (4) Ash (and qualitative examination).
- (5) Acidity.
- (6) Water-absorbing power.
- (7) Strength of jelly (shot jelly test).

The chemist should also examine the external aspects of the sample—the shrinkage and colour.

Moisture.—The percentage of water is determined by exposing a weighed quantity of the sample, finely powdered, to a temperature of 105° to 110° C. for fourteen hours, then cooling in the desiccator, and reweighing. From the loss in weight the calculation is made.

Glutin.—The glutin is determined by immersing a weighed portion in cold water, frequently stirring and changing the water, until all the colouring matter is extracted; then dissolving in hot water, filtering and precipitating the glutin in the filtrate with excess of a solution of tannic acid. The dense white precipitate formed is collected on a tared filter, washed with hot water, dried, and weighed. The calculation is made on the basis that the combination of tannin and glutin has the percentage composition—

Glutin	.	.	.	.	42.74
Tannin	.	.	.	.	57.26
					<hr/>
					100.00

This precipitation should take place in a faintly acid solution as the precipitate varies in composition according to the conditions.

The percentage of glutin in a glue naturally varies according to the quality and origin. A good bone glue will yield 50 to 52 per cent.; in skin glues it varies from 65 to 75 per cent.

Viscosity.—The viscosity is based on the length of time required by a glue liquor of known strength to flow through a burette, this is compared with water, which should take twenty-five seconds in flowing through the same. For this purpose a 1 per cent. solution of the glue is made and cooled to 18° C., being run through the burette from 0 to 50 c.c., and the number of seconds noted. The weaker the glue liquor,

the nearer it approaches the twenty-five seconds or water standard,—that is, the quicker is the flow. On the other hand, a high quality glue dissolved in the same proportion forms a more viscous solution, and consequently runs more slowly through the orifice of the burette. With water as a standard the time being twenty-five seconds, a poor glue will on the average take twenty-six to twenty-seven seconds, a medium twenty-eight to thirty seconds, and a good strong glue thirty-two to thirty-four seconds.

Ash.—A portion of the sample is finely powdered and then weighed in a tared crucible, in which it is slowly heated over the bunsen flame until carbonised; the crucible is then removed to the muffle and heated to bright redness until the carbon has all burnt off, then cooled under the desiccator, and weighed. The increase in weight of the crucible is the ash of the sample. This will range from 1 to 2 per cent. in a gelatine, 2 to 3 per cent. in a good glue, up to 6 or 8 per cent. in a common quality. The ash is subsequently examined for phosphates of lime and magnesia; bone glue contains both; skin glue is free from phosphates. Thus the origin of the sample can be traced.

Acidity.—Kistling determines the acidity by suspending 30 grams of the sample in 80 c.c. of cold water for ten to twelve hours in a flask connected with a condenser. The volatile acids are then driven over by a current of steam into a graduated cylinder, the flask being cooled and more water added from time to time. When the distillate amounts to 200 c.c., the distillation is stopped, and the distillate titrated with standard decinormal alkali. If the glue contains sulphurous acid, a known quantity of the standard alkali is previously added to the cylinder in order to absorb it and the excess of alkali is determined by standard acid.

Water absorption.—28.349 grams (= 1 oz.) of the sample are weighed in one piece and immersed in cold water (39° F.).

If the cake is thin, twenty-four hours are sufficient; for a thick cake forty-eight hours are necessary for a full absorption.

After immersion the cake should be clean at the edges, firm, and consistent. Carefully remove from the vessel, drain from all superfluous water, and weigh. The increase is the weight of water mechanically absorbed by the glue. The more consistent the jelly is, the greater will be the adhesive power of the glue, at the same time the larger the water absorption, the more economical will the glue be in actual use. With a poor and imperfectly clarified glue the increase in weight will be very low, the jelly will be soft and flabby, and the water highly charged with soluble matter. The absorption will vary from one and a half or two in a common quality, to four or six times the original weight with a medium glue. A strong glue will absorb six or seven, and a gelatine will gain, according to colour, from eight to ten times its weight.

Strength of jelly (shot jelly test).—This test, originally proposed by Lippowitz, is based on the weight-sustaining power of a jelly of known strength at a given temperature. It is made by covering one end of a small glass cylinder with a tin cap perforated in the centre. Through the perforation is passed freely a stout iron wire, at the lower end of which is soldered a piece of tin dipped like a saucer, the convex side resting on the surface of the jelly. To the upper end is also soldered a similar shaped piece of tin, to hold the weight necessary to force down the wire. The whole apparatus should weigh about 10 grams. The test is made with an 11 per cent. jelly at 18° C. For this purpose 31.17 grams (1.1 oz.) of the sample are dissolved in 283.4 c.c. (10 ozs.) of hot water, and allowed to stand in the cylinder for twelve hours to form the jelly. The apparatus is gradually loaded with weights until the convex side of the saucer-shaped piece of tin is forced into

the jelly. The greater the strength of the jelly the heavier will be the weight required. A medium to good quality at the above strength and temperature will carry 15 to 20 grams in addition to the weight of the apparatus.

In some recent researches, Setterberg and Cronquist have suggested a novel means of testing the tenacity of a glue. They soak unsized paper with a solution of the glue that has to be tested, and after drying ascertain its strength or breaking strain by means of a paper-testing machine.

S. Levites, in a paper read before the St. Petersburg Polytechnic Club (1899), advocates determining the melting-point of a jelly as the most suitable method of judging the value of a glue; and later, in the *Chemiker Zeitung*, Kistling, working on the same lines, urges the gelatine solidity and melting-point as the best criterion of the adhesive power.

However interesting these researches may be from a theoretical point of view, it is improbable that they will be regarded as infallible by those who, from practical experience, are most competent to judge the commercial value of glue.

CHAPTER IV.

USES OF GLUE, GELATINE, AND SIZE.

IN very many branches of industry, an agglutinant, such as glue, gelatine, or size, is of the utmost importance for successful working.

For instance, in the great textile trades, the consumption of both glue and size is considerable both in dressing and finishing coloured yarns and threads, sizing of worsted and other woollen warps, printing of fabrics, etc.

In the paper and bookbinding trades, the manufacture of cardboard boxes, millboards, and *papier maché*, also in the sizing, and applying of colours, as well as varnishing paperhangings, the amount employed is very large. For fancy and ornamental work, such as imitation leather wall coverings, fire, stove, and draught screens, imitation sculpture, mosaics, parquets, picture-frames, gilding, etc., the agglutinant performs an important part.

In joinery, carpentry, and cabinet work, the building up of railway and tramway vehicles, shop, house, office, and school fittings, household furniture, organs, pianos, billiard tables, veneering, panelling, and ornamental work in ships' saloons, the manufacture of wooden pipes, columns, and masts, etc., the glue-pot is a necessity.

For waterproofing and preserving tissues and fibres, ropes, cords, and twines, and in the preparation of transparent tablets for advertising, emery paper, substitutes for caoutchouc and gutta-percha, and in the utilisation of leather waste for making heels of boots and shoes, door and other

knobs, finger plates, door panels, plaques, trays, and even reels for sewing, glue again comes into play.

Gelatine has a more limited use in the arts. For confectionery and culinary purposes, and as a substitute for isinglass in the clarification of wines and beers, a quantity is used. It is also employed in the dressing of white fabrics, silk, and white straw hats, and the preparation of copying pads and photographic emulsions.

SOLUBLE AND LIQUID GLUES.

These are mainly combinations of glue with some ingredient, which destroys its gelatinising property but yet does not unduly impair its adhesiveness. They remain for a long time clear and syrupy, and owing to their portability are used for a variety of purposes.

The following are a few recipes :—

(1) Fifty parts of glue of a pale colour are dissolved in fifty parts by weight of hot water, in which fourteen parts of fused magnesium chloride have been dissolved. The solution, on cooling, does not gelatinise, but remains syrupy, the density varying according to the quantity of water used. In the manufacture of printing inks this preparation can be used as a substitute for gum.

(2) Ten parts of strong phosphoric acid are diluted with an equal weight of water, and then four parts of ammonium carbonate gradually added in the dry state. When the effervescence has subsided, a further five parts of water are added, and the liquid warmed on the water bath or steam chest to 70° C.; twenty to forty parts of glue, according to the consistency required, are then added, and the liquid stirred until all is dissolved.

(3) Twenty parts of glue are dissolved in an equal weight of hot water, there are then cautiously poured in, with stirring, four parts of strong nitric acid, the mixture being gently

heated until the nitrous fumes have been driven off, the liquid is filtered if necessary through fine shavings and allowed to cool.

(4) Dissolve ten parts of glue in seven parts of moderately strong acetic acid, to which one part of alcohol has been added, and filter. This forms a very useful cement and will even unite glass.

(5) In sixteen parts of hot water are dissolved eight parts of good glue, then one half to one part of hydrochloric acid is added, and one and a half parts of sulphate of zinc. The mixture is kept at 70° C. for eight hours, then filtered through fine shavings, and allowed to cool.

(6) Eight parts of molasses, and twenty-four parts of water, into which two parts of slaked lime have been mixed to form a thin cream, are heated on the water bath or steam chest for twenty-four hours; the lime is allowed to settle, and then the clear liquor decanted; in this is dissolved one-half to three-quarters of its weight of glue along with 2 per cent. of its weight of glycerine. The mixture is stirred well, and allowed to cool.

Other preparations are in use under different names, but their composition, however, varies but little from the above recipes. Nearly all are based on the solubility of glue in acids and their property of remaining liquid in a cooled state. All liquid glues should be clear and sparkling. On the other hand, in the various kinds of cements in which glue forms a predominant ingredient, the gelatinising property is left unimpaired, the glue being intimately mixed with some earthy or metallic oxide in order to impart body. Such cements set quite hard in a few minutes. Under this category may be included the white (Russian), chrome, steam, and water-proof glues, and many of the cements used for binding purposes for leather, china, glass-ware, electrical and chemical apparatus. The so-called marine glues of commerce are

mixtures of benzene, petroleum spirit or naphtha with indiarubber, shellac, or asphaltum ; they contain no glue.

Chrome and white Russian glues are prepared by adding pigments to the concentrated glue liquors before jellying. In a mixing for chrome glue 3 per cent. of chromic oxide is used, and in a white, 6 per cent. of sulphate of lead or 8 per cent. of zinc oxide.

STEAM AND WATERPROOF GLUES.

The former is a liquid glue, thickened with 10 per cent. of its weight of sulphate of lead ; a good composition for the latter is a mixture of eight parts of glue, four parts of linseed oil, and one part of litharge.

Compositions of glue and glycerine, or treacle, form an elastic mass, which is used for the making of printers' rollers, bookbinders' glue, and in the manufacture of plastic masses for children's toys, etc.

PART II.

MANURES.

CHAPTER V.

SOILS AND PLANT LIFE.

No branch of industrial inquiry is of greater importance than that which leads to an increase in the production of the soil.

As the rich soil of a country becomes exhausted of its most important elements through centuries of crude agricultural working, so agriculture declines provided that means are not taken to restore by artificial methods the wealth of plant nutriment which it formerly possessed, and, as it declines, so an increasing amount of the nation's money must be spent abroad to supply the necessary food. To a considerable extent that is the position of this country, as may be seen from the following.

Thus in 1910 we imported feeding materials of the following value:—

	£
Wheat	44,160,884
Barley	5,396,452
Oats	4,823,869
Maize	10,294,340
Wheatmeal and flour	5,510,905
Rice	2,587,198
Vegetables	3,656,470

During the same period, of animal food we imported :—

	£
Animals	4,028,672
Bacon	13,391,274
Beef	11,745,146
Hams	2,526,595
Mutton	9,802,858
All other kinds	7,384,402

We being essentially a manufacturing nation, dependent on the weaving of calicoes, building of ships and machinery, smelting of iron, and a thousand and one other industries, have neglected our agricultural interests, therefore we must look to the rising generation of farmers to extend their operations so as to reduce this enormous importation of food-stuffs. By gaining a better chemical and physical knowledge of the soil, by studying the functions of plant life and plant food, and the judicious application of manures, they may be in a better position to do this.

In this chapter the treatment of soils, their nutritive and productive power, and also the nature of plant life and food will be considered.

SOILS.

Soils are mainly composed of silicious matter—fine particles of rocks disintegrated by the agency of frost and water. This is the basis of most soils, but in addition there may be present carbonate, phosphate, and sulphate of lime, oxide of iron, potash salts, chloride of sodium, and silica, with decayed vegetable matter. Mechanically they may be considered as mixtures of sand, clay, calcareous marl and vegetable mould, and as one or other of these predominates, we have sandy, clayey, calcareous, or loamy soil. In 100 lb. weight of soil, these ingredients may vary as follows :—

Organic matter (mould)	. . . . .	1 lb. to 70 lb.
Clay	. . . . .	5 lb. to 35 lb.
Sand	. . . . .	20 lb. to 90 lb.
Calcareous marl	. . . . .	5 lb. to 20 lb.

Soils perform a mechanical action in absorbing the moisture and heat from the atmosphere, and at the same time their porous texture allows the circulation of air to provide the necessary oxygen for the germination of the seed. The soil is sufficiently open to admit the roots of a plant and yet sufficiently coherent to hold it in position; at the same time, owing to its capillarity, it acts the part of a carrier for conveying the mineral nutriment, which is dissolved in the circulating water and thus conveys it to the roots.

The mineral constituents on which the fertility of a soil depends are mainly phosphoric acid, potash, nitrogen in the form of ammonia, or nitrates, and, to a lesser extent, lime, oxide of manganese and iron, all in a soluble or easily assimilated form. Absence of these indicates a barren or exhausted soil, incapable of fertility without replenishment. To quote the words of a leading American agriculturist: "The farmer raises no crops which does not contain them, he sells no animal or vegetable product which does not take them from his farm, and he has no soil so rich that they, or some of them, need not be returned to keep up its fertility. Whatever course of cultivation he pursues, he should never lose sight of these elements, and he should pay no greater heed to the dollars and cents that he receives and pays out than to the nitrogen, phosphoric acid, and potash which constitute his real available capital, and whose increase or decrease marks the rise and fall of his true wealth."

The texture of soils is also an important factor in their productiveness. They should be loose, and yet not light enough to become easily dry, nor should they be so heavy as

to retain an excessive proportion of the water absorbed during rainy weather.

The capacity of soils for water varies according to their character—a sandy soil absorbs only 24 per cent. of its weight before saturation occurs; a calcareous soil, 28 per cent.; a clayey loam, 47 per cent.; and a peaty soil 80 per cent. Such a soil as the latter would require efficient drainage to be of any agricultural use.

Germination.—Plants develop from a germ which is contained within the seed. The seed is composed of a husk or cuticle enclosing the germ, along with a storage of food or endosperm to nourish it until it can absorb nutriment by means of root and leaf. The reserve food varies according to the character of the plant which is in embryo; in cereals, etc., it is starch, and in oil seeds, such as mustard, linseed, rape, etc., fat is also stored. Potash and phosphoric acid form the mineral ingredients. Under ordinary atmospheric conditions the germ lies dormant, but surrounded by favourable conditions in the soil, the seed swells, oxidation of the starch and fatty matter takes place, heat is developed within by the chemical action, and there results certain combinations by means of which the germ is nourished and grows, putting forth a tiny rootlet and rearing a tender stem through the soil, from which spring the first leaves.

PLANT LIFE.

Plants are largely composed of water, the organic framework containing carbon, oxygen, nitrogen, hydrogen, and sulphur, together with the mineral ingredients which are left as ash when the plant is burnt. By far the largest constituent of growing plants is uncombined water, then follow, according to their respective amounts, carbon, oxygen, hydrogen, nitrogen and sulphur. These elements are

united to form the starch, sugar, fat, alkaloids, and albuminoids present in the plants.

The composition of a growing plant (meadow grass) is given as follows :—

		Parts per 100.
Water		74.83
Organic matter	Carbon	11.74
	Hydrogen	1.28
	Nitrogen . . . . .	.43
	Oxygen	9.67
	Sulphur . . . . .	.19
Mineral matter		1.86
		<hr/> 100.00

The carbon is derived by decomposition from the carbonic acid contained in the atmosphere ; the oxygen and hydrogen are obtained from the water, and form, in conjunction with carbon, the starch, sugar, and fat of the plant ; the nitrogen is assimilated by the roots from the nitrogenous matter supplied to the soil ; while the sulphur is derived from the sulphates contained in the soil. If we eliminate the water we find the plant to be composed of 90 per cent. of matter taken from the atmosphere in the form of carbonic acid and moisture, with 10 per cent. of nitrogen and mineral ingredients abstracted from the soil.

It is therefore evident that the atmosphere plays the most important part in the growth of the plant, and this atmospheric action is mainly carried on by the agency of the leaves. In the structure of a plant we have the stem, leaves, and roots. Through the roots are absorbed all the mineral and nitrogenous matters and moisture ; the stem acts as a carrier and support ; while the leaves form the most important organs of the plant.

Animals, including man, inhale the oxygen of the atmosphere, which ultimately goes to transform the wasting

tissues of the body into carbonic acid, which is exhaled. If no means were provided to break up the carbonic acid thus formed, into its constituents, carbon and oxygen, the air would become surcharged with this gas and animal life would cease to exist. Nature, however, provides a remedy. The growing plant absorbs the carbonic acid through small openings in the leaves, termed stomata, and by means of a green colouring matter (chlorophyll) decomposes it into oxygen which is evolved and carbon which by chemical union with oxygen, hydrogen, and nitrogen, forms the carbohydrates and albuminoids essential for the growth of the plant.

The mechanical and chemical actions performed by the plant may be summarised as follows:—

- (1) Absorption by the roots of the mineral ingredients and moisture;
- (2) Decomposition of the atmospheric carbonic acid into carbon and oxygen by the chlorophyll of the leaves, assimilation of the carbon, and expulsion of the oxygen;
- (3) Combination of the carbon with the elements of water to form starch;
- (4) Conversion of the starch into sugar, cellulose, and other carbo-hydrates;
- (5) Absorption of nitrogen by the roots, as nitrate, and its union with the carbo-hydrates, to form amines and alkaloids, such as glutamine, quinine, brucine, etc.;
- (6) Their further change, by the action of sulphur, into that most important series of compounds termed albuminoids.

CHAPTER VI.

NATURAL MANURES.

MANURES may be broadly divided into two classes :—

- (1) Natural manures.
- (2) Artificial manures.

In the former class may be included all farmyard manures, litter, human excrementitious matter, and other raw animal and vegetable products which reach the farmer, and are used, because of the varying proportions of ammonia, phosphoric acid, and potash which they contain. In the latter class may be included all the phosphatic manures, whether these are used in the natural state as bones, rock phosphates, guanos, etc., or whether manufactured as superphosphates, prepared nitrogenous matters, special mixed manures, or mineral manures ; in addition to these there are other products, for instance, gypsum, common salt, kainite, marls, etc., which are used for fertilisation.

NATURAL MANURES.

The most important of all the natural manures is the farmyard manure. It is a mixture of solid and liquid excrementitious matter with straw and other vegetable remains, the solid matter containing the waste products from the body and undigested food, together with the insoluble mineral ingredients of the food partaken of by the animal, and the urine or liquid portion in which the larger proportion of the nitrogen exists as urea, easily decomposing to ammonia. In the following table the amounts of water and nitrogen con-

tained in the various farmyard and other nitrogenous manures are given :—

Manure.	Water	Nitrogen	Nitrogen
	per cent.	per cent.	Calculated on the Dry Substance.
Solid cow dung	85.9	0.32	2.27
Urine of cows	83.3	0.44	2.63
Solid horse dung	75.3	0.55	2.22
Horse urine	79.1	2.61	12.50
Sheep dung	63.0	1.11	3.00
Human excrements	86.0	0.71	2.95
Guano	19.6	5.00	6.14
Fresh bones	25.0	5.31	7.08
Horn shavings	9.0	14.39	15.81
Coal soot	15.6	1.35	1.59
Wood soot	15.6	1.15	1.36

Dr. Anderson gives the analysis of a mixed farmyard manure as follows :—

Water	72.48
Organic matter	13.94
(Containing nitrogen, 0.38.)	
Potash	0.32
Soda	0.16
Lime	0.59
Magnesia	0.02
Phosphoric acid	0.31
Sulphuric acid	0.12
Carbonic acid	0.52
Ferric oxide and alumina	0.45
Sand	11.09

100.00

These analyses show that farmyard manure contains only a small proportion of those fertilising ingredients necessary for the growth of plants, and that its use alone on an impoverished soil will not restore those elements on which depends the successful raising of a crop.

For restorative purposes, farmyard manure should be used in conjunction with "artificial" on a poor soil. It differs in action according to its origin. Pig, sheep, and cow dung decompose more slowly than horse dung, and, of the four, cow dung is the least valuable, owing to the lower proportion of available plant food.

Farmyard manure exercises a mechanical action on the soil, rendering it light and porous. For crops generally, a compost with bone dust or guano, or, in some cases, with wood ashes and lime, acts very beneficially on the soil, yielding excellent results and an increase in the weight of crops.

The quantities used for different crops vary—

Mangels require about 20 tons per acre.

Peas and beans " 18 "

Wheat " 12 "

Naturally the effect of these quantities are in proportion to the composition of the soil.

Human excrementitious matter is another manure of the same class, but it is rarely collected in a dry state.

By the adoption of the water-closet system in large towns, vast quantities of liquid and solid matter are produced; in some towns the solid matter is separated by gravitation, the liquid portion being treated with alumino-ferric or other chemicals, the precipitate formed carrying with it the valuable phosphoric acid in the form of insoluble phosphates of alumina and iron while the potash and ammonia salts remain in solution. The "sludge" formed is pressed, partly dried, and sold for manurial purposes, but it is of little value.

It has been urged that the herbage from the use of such a manure is rank and harsh, and that it engenders the spread of parasitic diseases.

The following is an analysis of sewage manure :—

Moisture	10.95
Organic matter	38.71
(Containing nitrogen, 3.06.)	
Lime	5.47
Oxides of iron and alumina	6.19
Alkaline salts	5.62
Phosphoric acid	4.63
Sand	25.22
	<hr/>
	96.79

The tops of all root crops, as also marine vegetable products like seaweed, form a very fair manure when ploughed into the soil. Time, however, is required for their decomposition and the yielding up of their mineral constituents. Dr. Griffiths enumerates the value of manures as follows :—

- “(1) They bring up plant food from the subsoil.
- “(2) They increase the nitrogenous constituents in the surface soil.
- “(3) As decomposition proceeds, carbonic acid is formed, which produces a disintegrating action upon the soil, thus converting some of the insoluble mineral constituents into soluble constituents.
- “(4) They warm the land, and add to its power of retaining moisture and ammonia.
- “(5) They promote the fertility of heavy clays by rendering them less sticky or adhesive.”

CHAPTER VII.

ARTIFICIAL MANURES—RAW AND OTHER PHOSPHATES.

BONES.

Raw Bones.—Raw bones rarely enter the farmyard. They are unsuitable for spreading on land, and their yield of phosphoric acid and nitrogen (existing as insoluble phosphate and gelatinous matter) to the soil is very slow. In the original state as received from the marine store dealers, butchers, and abattoirs, the farmer would pay for a high percentage of fat and moisture, which are of no manurial value; all the phosphates would be in an insoluble form, and he would require a mill driven by steam power to break or crush the bones even into half-inch or quarter-inch size, which would still be large for the purpose. To reduce to a fine state of division, and form a friable mass for the drill, is not possible, for the crushed bones would assume a pasty form owing to the organic matters and moisture present. Bone dealers do not, as a rule, sell to farmers, but treat directly with the fat, glue, and manure manufacturers, and it is the latter who, after extracting the fatty and gelatinous matters, sell to the farmer the residual bones, either as crushed bones, ground as bone meal, or in the form of soluble superphosphates.

Regarding the supply of home bones, it may be remarked that they are not equal to the demand, consequently manufacturers are compelled to obtain supplies from South America, Russia, India, and other countries. Foreign bones are all partially degreased and degelatinised by boiling or steaming before they are exported. Raw bones of home supply contain fat, organic and gelatinous matters, and mineral ingredients,

as, for instance, phosphate of lime, carbonate of lime, and a small proportion of alkaline salts. Now the fat, which averages $12\frac{1}{2}$ per cent. in raw bones, has no manurial value, yet it is worth £20 per ton for glycerine, candle, and soap-making; the organic matter, which is valuable only to the farmer by reason of the $3\frac{1}{2}$ to 4 per cent. of nitrogen which it contains, yields the glue of commerce, with a value of £28 to £32 per ton. In extracting these products, the bones undergo no deterioration, except a reduction in the percentage of nitrogen; on the other hand, the phosphates are increased proportionately by the elimination of the fat and gelatinous matter, the moisture is reduced to one-half, the bones being left in a fit condition to be crushed to any desired size, or ground to a fine meal, which can be more easily assimilated by the soil. The nitrogen is lowered to 1 or 2 per cent., according to the methods of extraction employed.

The following analyses by the author, show the chemical composition of raw bones. The samples may be taken as averages of the raw bones coming into the works on two different occasions:—

Moisture . . .	20·46	17·67
Organic matter ¹ . . .	34·09	33·84
Phosphate of lime . . .	39·21	42·15
Carbonate of lime . . .	4·16	3·52
Alkaline salts . . .	1·14	1·76
Sand (silica) . . .	·94	1·06
	<u>100·00</u>	<u>100·00</u>

¹ Containing nitrogen . . .	3·68	3·52
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Taking the average, these analyses show that the constituents of value for manurial purposes are—

Nitrogen . . .	3·57 per cent.	} = 49·54 per cent.
Phosphate of lime . . .	40·68 "	
Carbonate of lime . . .	3·84 "	
Alkaline salts . . .	1·45 "	

Therefore, if the raw bones could be reduced to a state of fineness suitable for the farmer, he would still be paying for 50 per cent. of inert material including moisture of no value to the soil, yet which would be of great commercial importance as glue and fat. Bones, as received in the farmyard, are half-inch, quarter-inch, or ground into bone meal. They are degreased and degelatinised, either by the benzene process, or by boiling in open pans, or steaming under pressure. If the benzene process is adopted, and a good system of glue extraction follows, then the treated bones, from their friable and porous nature, form an excellent bone meal for the farmer, although low in nitrogen; but as he buys on the basis of the units of nitrogen present, he suffers no monetary loss owing to this low percentage; on the other hand, the phosphates are high, running from 60 to 62 per cent. of tribasic phosphate, which is physically in a better condition to be absorbed by the soil. They have, however, not the same value as dissolved bones, in which the same percentage of phosphate is rendered more or less soluble by treatment with an acid.

The following analyses made by the author show the composition of bone meal prepared from bones treated by the benzene process and then degelatinised :—

	(1)	(2)
Moisture	9.25	8.54
Organic matter ¹ . . .	17.66	19.53
Phosphate of lime . . .	62.39	61.22
Magnesia and carbonate of lime	8.55	8.74
Alkaline salts . . .	.38	.59
Silicious matter . . .	1.77	1.38
	<u>100.00</u>	<u>100.00</u>

¹ Containing nitrogen . . . .	.97 per cent.	1.05 per cent.
Equal to ammonia	1.17 "	1.27 "

For raising the nitrogen 1 or 2 per cent. of a good organic nitrogenous material intimately mixed with the bulk in the required proportions will serve this purpose, without altering in the least the nature of the meal.

Boiled and Steamed Bones.—In bones the boiling or steaming process for the extraction of the fatty and gelatinous matters is not so economical as that of the benzene process; the extraction of fat and glue being less complete, the proportion of the latter left in the bones increases the nitrogen 1 to 2 per cent. Against this may be placed a lower percentage of phosphates, while the meal is not considered equal to that produced from bones treated with benzene.

The following are two analyses, by the author, of boiled and steamed bones :—

	Boiled Bones.	Steamed Bones.
Moisture	10.81	10.79
Organic matter ¹	25.97	22.48
Phosphate of lime	53.15	57.17
Magnesia and carbonate of lime	6.28	6.89
Oxide of iron . . . .	.27	Trace.
Alkaline salts	1.07	.86
Sand (silica)	2.45	1.74
	<hr/> 100.00	<hr/> 99.93
¹ Containing nitrogen	1.91 per cent.	1.64 per cent.
Equal to ammonia	2.81 "	1.99 "

Adulteration of bone meal is still practised, but not on such a large scale as formerly. The author recently tested a sample of material used by a firm for mixing with meal, and found it to contain 90 per cent. of sand.

Bone Ash.—On calcining a raw bone, a white or yellowish white product is obtained, retaining the shape of the original bone. This is the bone ash of commerce, and is chiefly

imported from South America. It has a limited use in the manufacture of superphosphates. Some samples which have come under the author's notice have tested as high as 88·43 per cent. of tricalcium phosphate, others again have been poor, containing only 70 per cent. Bone ash does not contain any nitrogen. A use for considerable quantities of bone ash of good quality is found in the manufacture of substitutes for cream of tartar for plain and fancy baking. The bone ash is treated with certain proportions of perfectly pure sulphuric and phosphoric acids to give the necessary acidity. The acidified product is then dried, ground to a fine powder, and mixed with flour in small proportions. The composition is sold under different names, and its strength is based on the number of c.c.'s of a decinormal alkali required to neutralise it.

Bone Charcoal.—Bone charcoal depends for its decolorising power partly on absorption of colouring matter as also partly on its oxidising action, owing to the large amount of oxygen which is condensed in its pores. In course of time this action gradually weakens, and it is then reburnt, but ultimately it loses its power. The char in this state is called "spent," and is of no further use to the sugar refiner. Containing a high percentage of phosphates, it is readily bought by the manure manufacturer at £2, 5s. to £2, 10s. per ton, and being in a finely divided condition it is easily treated with sulphuric acid, forming an excellent high-grade superphosphate. Samples of Leith, Liverpool and Greenock spent chars, examined by the author, gave respectively—

72·21	per cent.	tribasic phosphate.
70·24	"	"
74·00	"	"

The following is an average analysis of "spent" char :—

Carbon (nitrogenous)	20 65
Phosphate of lime	70 58
Carbonate of lime	5 17
Sulphate of lime	26
Oxide of iron	76
Sand (silica)	2 57
	<hr/>
	99 99
	<hr/>

MINERAL PHOSPHATES.

In the manufacture of superphosphates large quantities of rock or mineral phosphates are used in addition to the bone phosphates above described. The value of the unit, however, is lower than that of a bone phosphate. The presence also of considerable amounts of the oxides of iron and alumina, which cause reversion of the phosphate, and also carbonate and fluoride of calcium, lessens their worth.

Mineral phosphates are never used in their raw state, but are always converted into superphosphates, a proportion of their phosphates being rendered soluble by treatment of the material in a finely powdered condition with sulphuric acid. They are mined in many parts of the globe, and below is a brief description of the most important.

(1) *Canadian Phosphates*.—The Canadian phosphate, when pure, may be considered as a true apatite, a definite combination of phosphate and fluoride of calcium having the formula $3\text{Ca}(\text{PO}_4)_2 + \text{CaF}_2$.

Canadian apatite is considered one of the best of mineral phosphates for the preparation of superphosphates, owing to the high percentage of phosphate of lime it contains. The following analyses by Dr. Voelcker express the composition of apatite :—

	(1)	(2)	(3)
Moisture, water of combination, and loss on ignition	·62	·10	·11
Phosphoric acid ¹	33·51	41·54	37·68
Lime ²	46·14	54·74	51·04
Oxides of iron and alumina, and fluorine	7·83	3·03	6·88
Silica	11·90	·59	4·29
	<hr/> 100·00	<hr/> 100·00	<hr/> 100·00

¹ Equivalent to tribasic phosphate of lime 73·15 90·68 82·26

² Excess of lime over the amount required to
form tribasic phosphate 6·50 5·60 6·47

The excess of lime is a guide to the economical working of a mineral phosphate: the higher the excess the greater the amount of acid necessary to work up the mineral, and thus the more costly is the superphosphate produced.

Canadian apatite occurs in distinct crystalline masses usually of a pale green colour, but sometimes of a reddish tint, and it is found in the Laurentian rocks of what the geologists term the Palæozoic age. Undoubtedly the heavy freight to ports in the United Kingdom check to a large extent the use of this valuable phosphate.

(2) *Norwegian Apatite*.—Is closely allied to the Canadian deposit, but the tricalcium phosphate is combined with calcium chloride, the mineral being classed as a chlor-apatite. For certain reasons, little is used in this country, but it forms a valuable source of phosphate for manure-making. Samples of the mineral show 76 to 80 per cent. of phosphates, with very little of the oxides of iron and alumina.

(3) *South Carolina Land and River Phosphates*.—These phosphates, together with a similar class from Florida, are largely exported to England. The land phosphates, in the form of nodules, are mined round Charlestown. To some extent these are fossiliferous, and they are of a pale yellow

or brown colour, according to the proportion of oxide of iron present. The river phosphates are dredged all the year round by large "bucket" dredgers working on the Savannah, Saluda, and other rivers; on raising they are well washed to free them from sand, dried, and exported. The river phosphates are very dark in colour, and much harder than the "land" variety. From the *Proceedings of the Royal Agricultural Society* the following analyses are taken as representing the average composition of these phosphates:—

Land Phosphates.

	(1)	(2)
Water and water of combination	7.40	2.29
Phosphoric acid ¹	26.50	24.29
Lime	37.20	38.71
Oxides of iron, alumina, magnesia, and carbonic acid	16.27	17.28
Silica	12.63	17.43
	<hr/> 100.00	<hr/> 100.00
¹ Equivalent to tribasic phosphate of lime	57.85	53.02

River Phosphates.

	(3)	(4)
Water, water of combination, and loss on ignition	4.07	1.56
Phosphoric acid ¹	28.44	26.89
Lime	45.07	42.28
Magnesia, oxides of iron and alumina, carbonic acid	15.16	18.47
Silica	7.26	10.80
	<hr/> 100.00	<hr/> 100.00
¹ Equivalent to tribasic phosphate of lime	62.09	58.70

On comparing the phosphate of lime in these analyses, it will be noticed that the "river" variety has a higher percentage than the "land" phosphate, and consequently is of more value.

(4) *Navassa Phosphates*.—These are obtained from the island of Navassa in the Caribbean Sea, and exist in the form of nodules of a reddish-brown colour. They contain a high percentage of phosphate of lime, and are well adapted for the manufacture of superphosphates. The limited production, high working charges, freightage, etc., render at present their shipment to this country unremunerative. The composition of these phosphates is seen from the following analyses of bulk samples:—

	(1)	(2)
Water, free and combined	12.08	10.90
Phosphoric acid ¹	30.21	31.08
Lime	35.32	36.54
Magnesia, carbonic acid, oxide of iron, alumina	19.65	17.78
Silica (sand)	2.74	3.70
	<hr/> 100.00	<hr/> 100.00
¹ Equivalent to tribasic phosphate of lime	65.94	67.85

(5) *Sombrero Phosphates*.—The phosphates from the island of Sombrero, in the group of the Leeward Islands in the Caribbean Sea, are practically exhausted. They were of high quality, and averaged 70 per cent. of tricalcic phosphate.

(6) *Aruba Phosphates*.—Infrequently cargoes are to be found in the market of this class of mineral phosphates. Although rich in phosphates, the presence of considerable quantities of carbonate of lime, also of oxides of iron and alumina, detracts from their value. The phosphate of lime averages 72 per cent.

(7) Other West Indian islands produce to a limited extent mineral phosphates of varied composition, Maracaibo phosphate, from the island of that name, yielding the highest percentage of phosphate of lime (average 78 per cent.), with low amounts of oxide of iron and alumina. Maracaibo

mineral forms an excellent superphosphate. The small islands of Redonda and Alta Vela, in the West Indian group, yield a mineral phosphate in which the lime is replaced by alumina and ferric oxide, forming phosphates of alumina and iron. Owing to their poorness in lime, and also to the fact that alumina and iron are detrimental, these minerals cannot be employed in the manufacture of superphosphates. Samples of Redonda and Alta Vela phosphates show respectively 70 and 50 per cent. of iron and alumina phosphates. Their agricultural value is considered low, although a leading authority says, from his own experience, that good crops can be got with the use of Redonda in a fine state of division. Several countries in Europe produce large quantities of mineral phosphates, distinguished as coprolites, phosphorites, etc. Some of these are valuable owing to the high percentage of phosphate, and the presence of but moderate quantities of carbonate of lime, iron, and alumina. Others again are low in phosphates, heavily impregnated with iron, and hardly worth the cost of exporting.

ENGLISH COPROLITES.

English coprolites are found in Cambridgeshire, Suffolk, Norfolk, and Bedfordshire; the finer qualities being furnished by the first-named county, from the Upper Greensand, and are of a grey colour. They are largely used, and well suited for the manufacture of superphosphates. The following analyses represent their composition:—

	(1)	(2)
Water	2.30	3.79
Water of combination	1.50	
Phosphoric acid ¹	26.05	29.14
Lime	43.68	45.05
Oxide of iron and alumina	18.70	19.68
Silica	7.77	2.34
	<hr/> 100.00	<hr/> 100.00

¹ Equivalent to tribasic phosphate of lime 56.87

63.62

Suffolk Coprolites.—Suffolk coprolites are of a brown colour, and somewhat inferior to the Cambridge variety. They contain from 48 to 52 per cent. of calcium phosphate with 14 to 16 per cent. of carbonate of lime. The superphosphate formed when they are used is lower in quality than that made from the Cambridge phosphate.

Bedfordshire Coprolites.—These coprolites may be classed with the Suffolk phosphate. They are also of a brown colour, and contain—

Moisture and water of combination	3.35
Phosphoric acid ¹	23.47
Lime	36.29
Ferric oxide	5.39
Alumina, magnesia, and fluorine	7.24
Carbonic acid	3.45
Silica	20.81
	<hr/>
	100.00

¹ Equivalent to tribasic phosphate of lime 51.24

French Phosphorites.—The richest mineral deposits of France are those mined at Loire and Garonne, known in this country as French or Bordeaux phosphates. They have a yellowish-brown colour, and are very hard. With sulphuric acid they are readily dissolved, and form high-grade superphosphates. The following analyses are representative of their composition—

	(1)	(2)
Water	2.60	.89
Water of combination	2.62	2.58
Phosphoric acid ¹	34.46	31.50
Lime	46.11	41.12
Oxide of iron	10.77	13.73
Alumina and carbonic acid		
Silica	3.44	10.18
	<hr/>	<hr/>
	100.00	100.00

¹ Equivalent to tribasic phosphate of lime 75.25 68.76

Around Bologne there exist phosphatic deposits, in appearance and chemical composition similar to the inferior qualities of our own coprolites. They have but a limited use in this country for the manufacture of low-grade superphosphates. The calcium phosphate they contain averages about 43 per cent.

Belgian Phosphates.—These deposits exist in a fine powdery condition, and after washing and drying are brought up to a strength of about 46 to 47 per cent. of phosphate. They are not used alone, but in conjunction with high-grade phosphates. The addition of these increases the porosity and dryness of the superphosphate.

German Phosphates.—The best known and probably the most extensive deposits of German phosphates are found near the river Lahn below Weelbach, to which the name of Nassau is given.

Some samples, representing limited quantities, test as high as 75 per cent. of phosphate, but the bulk is of low quality, being found mixed with varying proportions of clay, limestone, ironstone, phosphate of alumina, etc. The importations to this country are not now of any importance. The phosphate averages about 50 per cent.

Spanish Phosphorites.—Spain supplies a large quantity of rich phosphates, mined in the province of Estramadura. They are of a light yellow colour, with a crystalline structure, and belong to the class of fluor-apatites. The following table shows their composition:—

	From Caaceras.	From Montanehez.
Water	21	16
Phosphoric acid ¹	38.85	39.09
Lime	51.65	51.77
Fluorine, carbonic acid, and a little oxide of iron	2.41	3.07
Silica (quartz rock)	6.88	5.91
	<hr/> 100.00	<hr/> 100.00

¹ Equivalent to tribasic phosphate of lime

84.82

85.33

Thomas Slag.—In the manufacture of “basic” steel, a residual slag or cinder known as Thomas slag is produced, containing on an average about 15 per cent. of phosphoric acid, with 20 to 22 per cent. of iron as ferrous and ferric oxides. It has been found that a large proportion of the phosphoric acid (existing as phosphate of iron) in this is readily soluble in weak acid solutions, and thus capable of being made available for agricultural purposes. According to Dr. Wagner, the cinder is well adapted for moss and peaty meadow soils when ploughed well in; and the same authority advocates its use as a manure for oats, wheat, barley, and flax, in the proportion of about 3 cwt. per acre.

For the successful use of the “Thomas cinder,” it must be ground to an impalpable powder to enable the phosphoric acid to be rendered soluble and thus capable of being absorbed by the roots.

Notwithstanding the excellent virtues attributed to its use by German agricultural authorities, the consumption in this country (which produces over 100,000 tons of this slag per annum) is not great, farmers generally taking an unfavourable view of its fertilising value, some remarking that its action is harsh, and that after a time the soil becomes “burnt”.

GUANOS.

Guanos.—The guanos of commerce may be divided into—

- (1) Guanos proper ;
- (2) Guano phosphates.

Guanos proper are the rich excrementitious matter of sea-birds which inhabit the Peruvian coast and oceanic islands. They have undergone some little decomposition by the action of tropical rains, and consist of uric acid, urate of ammonia, with varying proportions of phosphate of lime and ammonia, sulphates and chlorides of potash, and soda, and silicious matter; the nitrogenous portion amounting to two-

thirds, and the mineral matter one-third of the whole,—the nitrogen equivalent being from 17 to 19 per cent. All guanos at an early period have been very rich in nitrogen, but through the action of rain and other atmospheric influences they have undergone more or less change, the water converting the urates into volatile carbonate of ammonia and other soluble ammonium salts. When the atmospheric action is prolonged, nearly, if not the whole, of these ammonia compounds are removed by solution, the deposits becoming mainly phosphates with 1 to 2 per cent. of nitrogen, and are known as guano-phosphates. Guanos are complete manures in themselves, containing all the necessary fertilising ingredients in the form of soluble ammonia salts, phosphoric acid, and potash. They can be used with success on either heavy or light soils of a clayey or sandy nature, forming an excellent material for use on nearly all crops.

Guanos are now sold on the basis of the units of nitrogen they contain, and thus the farmer is protected from adulteration, which was formerly practised to a very large extent. If he buys on a basis of 17 to 18 per cent. of nitrogen or as low as 1 to 2 per cent., he pays accordingly. It is to his interest, however, that the certificate of analysis should guarantee the sample to represent a true average of the bulk, and not one selected because of its richness.

As is well known, guanos, especially when moist, emit a strong, pungent, ammoniacal odour, due to volatilisation of carbonate of ammonia, and on standing for any length of time this loss becomes serious. To fix this ammonia and at the same time to bring the guanos into a dry and friable condition, easily worked with the drill, many manure manufacturers now treat them with strong sulphuric acid in the mixing trough of the manure shed, the acid fixing all the ammoniacal compounds as soluble sulphate of ammonia, also rendering the phosphates they contain largely soluble, and

producing a powdery guano liable to no further change by exposure. In such a form the guanos form a quick-acting manure, containing 20 to 23 per cent. of soluble phosphates, with about 9 per cent. of ammonia. During this mixing, the nitrogen can be increased by the addition of dried blood or sulphate of ammonia, whichever may be considered most suitable.

The following is a description of the leading guanos and guano-phosphates that have been, or are at the present time, used for agricultural purposes:—

(1) *Angamos Island Guano*.—From the island of Angamos, off the Peruvian coast, a rich, dry excrement is imported into this country. It is of a light yellow colour, and contains 19 to 21 per cent. of nitrogen, with 12 to 13 per cent. of phosphates, part of these being soluble. The following analyses represent its composition:—

	(1)	(2)
Moisture	7.24	8.76
Organic matter and salts of ammonia ¹	69.01	69.96
Phosphates of lime and magnesia	12.06	12.07
Alkaline salts	9.02	8.27
Silica	2.67	.94
	<u>100.00</u>	<u>100.00</u>
¹ Containing nitrogen	21.15	19.30

(2) From the Peruvian islands of Chenchá, Guanape, and Ballestas, considerable quantities of a fairly rich Peruvian guano have been exported at different times. They contained—

	Chenchá Islands.	Guanape Island.	Ballestas Islands.
Water	13.67	17.79	19.19
Organic matter and ammonia salts ¹	52.05	42.62	48.19
Calcium and earthy phosphates	22.78	25.45	20.69
Alkaline salts	9.67	11.92	9.40
Sand	1.83	2.22	2.53
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>
¹ Containing nitrogen	13.61	10.04	13.60

(3) *Pabillon de Pica Guano*.—This group of Peruvian islands exports a rich guano, very dry, and of a reddish-yellow colour. A sample, on analysis by the author, gave—

Moisture	2.35
Organic matter and salts of ammonia, ¹ by ignition	63.75
Phosphoric acid	9.09
Lime,	10.14
Magnesia	2.65
Ferric oxide	Trace
Alkaline salts	7.38
Silica	4.64
	<hr/>
	100.00
¹ Containing nitrogen	17.03

(4) *Ichaboe Guano*.—From the Ichaboe Islands, on the south-west coast of Africa, we import a moderate quantity of a rich guano. A sample, on analysis by the author, showed the following composition :—

Moisture	12.28
Organic matter and salts of ammonia, ¹ by ignition	51.25
Phosphoric acid	12.09
Lime	12.25
Magnesia	1.06
Alkaline salts	4.83
Silica	6.24
	<hr/>
	100.00
¹ Containing nitrogen	14.22

Guano-Phosphates.—The guano-phosphates are distributed over a wide area, being found in Bolivia, Peru, and as far south as the Falkland Islands and Patagonia; they exist also in considerable quantities in some of the West Indian islands, the Gulf of California, and South Africa. They contain from 1 to 2 per cent. of nitrogen, with varying proportions of phosphates. The guano-phosphates have a reddish-yellow

colour, and are generally found in a powdery condition. As before mentioned, these phosphates were originally rich guano deposits, which at different periods have been subjected to heavy rainfall, resulting in the decomposition of the nitrogenous matter and the washing out of the larger portion of the soluble ammonia salts thus formed.

They are mainly used for the manufacture of "dissolved guano," the nitrogen being increased by the addition of dried blood or sulphate of ammonia, they are also used for the manufacture of superphosphates for special manures.

Guano-phosphates, owing to deficiency in nitrogen, have a lower value than the guanos proper.

The following constitute the chief guano-phosphates that are used for manufacturing purposes:—

(1) *Megillones Guano-Phosphate*.—This guano-phosphate is found on the high tableland near the Bolivian coast. It has a bright red colour and occurs in the form of a powder. The nitrogen is low and the phosphates are in part soluble.

Dr. Voelcker gives the composition of two cargo samples as follows:—

	(1)	(2)
Moisture	8.76	7.45
Organic matter and salts of ammonia ¹	6.49	7.34
Phosphoric acid ²	34.40	30.72
Lime	37.60	36.81
Ferrie oxide . . . . .	.54	.38
Magnesia	2.83	8.56
Alkaline salts	5.76	
Carbonic acid . . . . .	.45	.75
Sulphuric acid	1.68	6.76
Silica	1.49	1.23
	<hr/> 100.00	<hr/> 100.00
¹ Containing nitrogen . . . . .	.98	.89
Equivalent to ammonia	1.19	1.08
² Equivalent to tribasic phosphate of lime	75.09	67.06

Owing to the high percentage of phosphates, and to the fact that part are in the soluble form, also due to its dry and powdery condition, this phosphate forms a good manure when used either alone or dissolved by means of acid. For some crops it is considered equal to Chili saltpetre.

(2) *Curacao Guano-Phosphate*.—The phosphate from Curacao Island, South America, is an example of a guano from which the whole of the ammoniacal material has been removed by the prolonged action of water. It is composed of phosphate and carbonate of lime mixed with alkaline sulphates and silicates, and from its high percentage of phosphoric acid is found very suitable for the manufacture of superphosphates.

In a sample the author found—

Moisture	9.33
Organic matter	4.28
Phosphoric acid	34.83
Lime	42.21
Carbonic acid	3.05
Magnesia . . . . .	.59
Potassium and sodium sulphates	3.25
Sodium chloride	1.57
Silica . . . . .	.89
	<hr/>
	100.00

(3) *Falkland Islands Guano-Phosphates*.—The Falkland Islands supply a phosphate containing a fair proportion of ammonium salts. Unfortunately these guanos are heavily charged with water, and have a strong pungent smell owing to the volatile ammonium carbonate which is evolved. Such phosphates are best treated with sulphuric acid, to fix the ammonia and render them dry and friable for use with the drill.

The following analyses by Dr. Voelcker represent their composition :—

	(1)	(2)
Moisture	33.43	35.86
Organic matter and salts of ammonia ¹	21.42	26.07
Phosphates of lime and magnesia	32.04	22.01
Carbonate of lime	2.52	5.64
Alkaline salts	6.22	7.34
Silica	4.37	3.08
	<hr/> 100.00	<hr/> 100.00
¹ Containing nitrogen	4.81	4.42
Equivalent to ammonia	5.23	5.36

(4) *Raza Island Guano-Phosphate*.—From the Gulf of California is obtained a phosphatic guano of high strength, containing $\frac{1}{2}$ to 1 per cent. of nitrogen. The deposit is very dry and powdery, and has a reddish-yellow colour. It is a valuable addition to the manure shed for superphosphate making. The following cargo samples illustrate its value for manurial purposes:—

	(1)	(2)
Water	4.83	1.30
Organic matter ¹ and combined water	12.72	9.80
Phosphoric acid ²	34.33	40.31
Lime	37.36	37.21
Magnesia	1.76	7.18
Ferric oxide . . . . .	.50	
Alumina . . . . .	.81	
Carbonic acid . . . . .	.46	
Alkaline salts	5.54	4.20
Silica	1.69	
	<hr/> 100.00	<hr/> 100.00
¹ Containing nitrogen	1.04	.37
Equivalent to ammonia	1.26	.45
² Equivalent to tribasic phosphate of lime	74.94	88.01

(5) *Baker Island Guano-Phosphate*.—This deposit is relatively rich in phosphate of lime, but contains little or no nitrogen. Like other guano-phosphates, it is well suited for treatment with sulphuric acid, being dry and in a fine state of division. Its composition is seen from the following analyses:—

	(1)	(2)
Water	12·00	4·71
Organic matter ¹	6·25	6·17
Phosphoric acid ²	32·32	39·44
Lime	42·34	43·01
Magnesia	0·76	2·32
Ferric oxide	0·14	0·96
Alumina	0·09	
Sulphuric acid	1·19	
Carbonic acid	2·99	0·27
Alkalies	1·78	2·33
Silica	0·14	0·79
	<hr/> 100·00	<hr/> 100·00
¹ Containing nitrogen . . . .	...	0·84
Equivalent to ammonia . . .	...	0·41
² Equivalent to tribasic phosphate of lime	70·55	86·11

(6) Other supplies are obtained from Patagonia, Sydney Island, Jarvis Island, Aves Island, and from Australia. These consist principally of phosphate of lime with varying proportions (·25 to ·5) of nitrogen, and their value depends partly on condition and partly on the percentage of phosphate they contain. Like the other guano-phosphates already described, they are chiefly used for dissolving purposes.

CHAPTER VIII.

MINERAL MANURES, SUPERPHOSPHATES, ETC.

SODIUM CHLORIDE (COMMON SALT).

COMMON salt, or that quality described as agricultural salt, is now used in considerable quantities for manurial purposes.

Chemically, it is a combination of the metal sodium with chlorine gas, the resulting compound being termed sodium chloride (NaCl).

Geographically, it is distributed in deposits over a wide area, being found in practically inexhaustible quantities in the districts of Nantwich and Northwich in Cheshire, and Droitwich in Worcestershire; in the State of Michigan and other places on the American continent; in Russia, Germany, Austria, and Persia. It also exists in large amount in sea water.

In England, salt is not mined, in the ordinary sense of the term, but is dissolved as brine, a saturated solution of the salt, which is pumped at considerable depths in the earth's crust, from deposits belonging to what is known by geologists as the Triassic period. The brine is evaporated in pans to form the different kinds of salt found in commerce, the finest quality of which is the domestic table salt.

The following table of analyses, made by G. E. Cooke, gives an idea of the composition of various samples taken from—1, Northwich (Cheshire); 2, Dreuze (Lorraine); 3, Droitwich (Worcestershire); 4, Goderich (Ontario); 5, Saginaw (Michigan, U.S.A.); 6, Nantwich (Cheshire).

	(1)	(2)	(3)	(4)	(5)	(6)
Sodium chloride .	96·36	97·59	96·93	97·03	92·97	90·23
Calcium chloride .	·01	...	...	·01	1·09	...
Magnesium chloride .	·02	...	·02	·03	·50	...
Calcium sulphate .	1·17	1·02	3·05	1·43	·33	1·68
Carbonates of lime and magnesia .	...	...	...	...	...	·75
Oxide of iron .	...	...	...	...	...	·87
Sulphates of sodium and magnesia .	...	·80	...	...	...	...
Insoluble matter .	...	...	...	...	·01	...
Water .	2·24	·50	...	1·50	5·10	6·38
	<u>99·80</u>	<u>99·91</u>	<u>100·00</u>	<u>100·00</u>	<u>100·00</u>	<u>99·91</u>

Agricultural salt contains from 90 to 93 per cent. of sodium chloride, is rather moist, and contains a small proportion of iron.

Although formerly disputed, it is now generally recognised by agriculturists that salt is beneficial to the soil when applied in moderate quantities, either alone or in conjunction with sodium nitrate. Not only as a plant food is it valuable, but its action on the land is considerable, keeping it cool and moist, and destroying all soil vermin.

Johnstone, in his work on *Agricultural Chemistry* (1852), says salt "destroys small weeds, improves the quality of pastures, rendering them more palatable; strengthens and brightens the straw, and makes the grain heavier per bushel, both of wheat and oats. It has also been observed to produce specially good effects on mangel-wurzels." Later, Liebig speaks a word in its favour. He says: "We have every reason to believe that where the crops are increased by manuring with common salt alone, or when the favourable influence of salts of ammonia or nitrate of soda is augmented by the addition of common salt, the operation of the three salts essentially depends upon their power of diffusing the

nutritive substances present in the soil or of preparing those substances for absorption"; and after quoting the results of some experiments carried out by the Bavarian Agricultural Society, continues: "In both these series of experiments the crops of corn and straw were remarkably increased by the addition of common salt". Professor Shelton, a leading American agriculturist, further shows its value in this respect on wheat. He writes: "a dressing of 300 lb. salt per acre on two plots gave an average increase of close on 9 per cent. of cleaned grain as compared with plots not dressed, as well as an increase of straw".

Common salt also plays a very important part in decomposing certain organic and inorganic constituents of the soil, rendering them soluble and in a fit state to be absorbed by the plant as food.

POTASH SALTS.

Kainite.—The compounds of potassium used in agriculture are the sulphate and chloride. The sulphate of potash is never used in the pure form, but in combination with magnesium salts, forming the mineral kainite. This natural product is obtained from the celebrated mines of Stassfurt, in Germany, and exists as sulphate of potash combined with chloride and sulphate of magnesia. Authorities state the formula to be $\text{MgSO}_4\text{KCl}6\text{H}_2\text{O}$, but it is composed of the sulphates of potash and magnesia with magnesium and sodium chlorides and when pure has the formula $\text{K}_2\text{Mg}(\text{SO}_4)_2$, MgCl_2 , $6\text{H}_2\text{O}$, with common salt. It has a yellowish-grey colour, and effloresces in a dry atmosphere.

The following is an analysis of a sample of kainite by the author:—

Total water, mechanical and in combination	15.16
Oxides of iron and alumina . . . . .	.34
Sulphate of potash	25.07
Chloride of sodium	20.51
Chloride of magnesia	18.13
Sulphate of magnesia	17.08
Sulphate of lime	2.29
Insoluble matter	1.42
	<hr/>
	100.00

The sulphate of potash present is equal to 13.54 per cent. of potash (K_2O). Generally, kainite is not used alone, but in conjunction with superphosphates, guanos, and in many mixed manures, it is one of the leading sources for enriching these manures with their potash food.

Potassium Chloride, Chloride of Potash.—The chloride, or muriate of potash, as it is sometimes termed, is obtained from the Carnellite deposits of the Stassfurt region. Carnellite is a combination of the chlorides of potash, and magnesia with water of crystallisation— $KClMgCl_4 \cdot 6H_2O$. Dr. Thorpe gives the analysis of a sample of this mineral deposit as follows :—

Chloride of potash	15.7
Chloride of sodium	21.5
Chloride of magnesia	21.3
Chloride of calcium . . . . .	.3
Sulphate of magnesia	13.0
Insoluble matter	2.0
Water	26.2
	<hr/>
	100.0

To prepare potassium chloride from this mineral the carnellite is crushed, boiled with water, and the chloride of potash crystallised out. By recrystallisation it is obtained in a very concentrated state, containing 98 to 99 per cent. Two

analyses by the author of the commercial product, guaranteed 98 per cent. chloride, were as follows :—

	(1)	(2)
Chloride of potash . . .	98·81	98·05
Sodium chloride . . .	·38	·63
Chloride of magnesia . . .	·26	·58
Sulphate of magnesia . . .	·29	·36
Insoluble matter . . .	·14	·38
	<u>99·88</u>	<u>100·00</u>

Many manure manufacturers use the chloride as it is relatively a cheaper potash compound, being much more concentrated than kainite. Other sources of potash exist in suint or wool fat, kelp, wood ashes, fish offal, etc.; the low percentage of potash, however, makes their use very limited. They cannot compete with the Stassfurt salts.

Potash salts, used as an admixture with phosphates, are recognised as excellent manuring agents for nearly all crops, wheat, oats, barley, potatoes, turnips, peas, beans, and grass all require these ingredients.

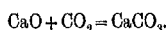
CALCAREOUS MANURES.

Under this heading may be placed those mineral compounds in which lime, as carbonate and sulphate, predominates. They comprise limestone, calcareous marls, and gypsum. The mountain limestone found in many districts of England and Scotland is the source of the greater part of the lime used. Limestone is calcium carbonate, and lime the calcium oxide, and for the conversion of the former into the latter the limestone is heated to bright redness with fuel in specially contrived kilns, with the result that carbonic acid is driven off, leaving the lime behind. The following equation represents this action :—



Limestone = Lime + Carbonic acid.

A pure carbonate yields 56 per cent. of lime, or a little more than half its weight. On exposure to the atmosphere the reverse action takes place, the lime absorbing carbonic acid from the air, becoming converted again into carbonate of lime, thus—



Lime + Carbonic acid = Carbonate of lime.

Lime, if it is to retain its strength, should be kept well covered if stored for any length of time. Lime plays a double part in agriculture,—firstly, it is a necessary plant food, being found in the ashes of nearly all cereal and root crops, as will be seen from the following table of analyses, by Dr. Griffiths (*Journal of the Chemical Society*):—

	Lime per cent. in mineral matter.
Mangel-wurzel (roots)	13.62 per cent.
Meadow hay	18.31 „
Beans	7.12 „
Cabbages	15.66 „
Wheat (grain)	10.66 „
Turnips (roots)	13.02 „
„ (leaves)	35.62 „
Potato (tubers)	3.02 „
„ (haulm)	17.07 „

It will readily be evident from this that no crops can grow to perfection without lime; secondly, its chemical and physical action on the soil is such as to render it of great value to the farmer. Lime corrects the “sourness” in soils,—that is, it neutralises acidity due to free organic acids which are inimical to the proper growth of vegetation. Lime plays a very important part in decomposing decaying vegetable matter, according to Liebig, also in destroying the fungi formed by decaying organic matter, thus preventing the “sickening” of such deep-rooted plants as turnips, clover, peas, beans, etc.

Lime also acts chemically upon insoluble forms of mineral matter in the soil, decomposing them, and rendering a portion of their constituents available as food for plants. Finally it is favourable to the growth of bacteria upon which to a certain extent plants depend.

MARLS.

Marls are mixtures of carbonate of lime with clay, in which the calcareous or the argillaceous constituents may predominate according to the region in which they are found. In limestone districts marls may consist practically of an impure carbonate of lime or limestone; on the other hand, red marls of the Triassic age contain but a small percentage of carbonate of lime, and as the agricultural value of marls depends on the carbonate they contain, the red marls, owing to this deficiency, may be considered of little value to the farmer. According to Dr. Griffiths, the analysis of a sample of chalk-marl gave:—

Carbonate of lime	69.23
Phosphate of lime	0.63
Potash and magnesia	0.45
Sulphate of lime	Trace
Oxides of iron and alumina	0.36
Soluble silica	8.29
Sand	18.55
Moisture	2.49

Marls are valuable additions to land, containing but little lime. Chemically their action is the same as that of lime, but their action is not so rapid.

SULPHATE OF LIME OR GYPSUM.

Gypsum is a soft crystalline mineral which is simply ground to powder as found in commerce; it is a hydrated sulphate of calcium, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, and, when burnt, forms the well-known plaster of Paris. It is an abundant mineral found

in association with marls and rock salt in many districts. In a crystalline or fibrous state it exists as alabaster or satin-spar. When gypsum is resolved into its components, lime, sulphuric acid, and water result; these may be regarded as nutritive substances, therefore it has a certain manurial value as a food for plants. For grass and meadow lands, potatoes, turnips, and clover, gypsum forms an efficient manure in developing the growth. As regards the latter, Dr. Pincus, in some interesting investigations, shows the increase of the crop when manured with gypsum to be—

	Cwt. of Clover Hay per acre.
Without manure	34.56
With gypsum	48.96

Gypsum also plays a very important part in helping to liberate potash and magnesia from the rock materials of the soil, converting these elements into a soluble condition ready for assimilation by plants. This action is no doubt due to a complex reaction in which sulphuric acid is liberated and this acting on the earthy matter dissolves the bases; this acid increases in the plant in proportion to the gypsum used. In the ash of air-dried clover hay Dr. Pincus found :—

	Plot unmanured.	Manured with Gypsum.
Sulphuric acid	6.95 per cent.	7.96 per cent.

A dressing of 2 cwt. of gypsum to an acre is sufficient of this manure.

PREPARED NITROGENOUS MANURES.

Nitrogenous manures are partly inorganic and partly organic; their value depends principally on the nitrogen they contain, whether it is in the form of nitrate, or ammonia, or organic nitrogen compounds.

AMMONIUM COMPOUNDS.

Ammonia is a gas (NH_3) which combines with acids to

form the ammonium compounds which are almost all soluble in water. Some of the more important are given with the available nitrogen which they contain, together with their values, as follows:—

	Percentage of Nitrogen.	Value per ton.
Ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$. . .	21·21	£13 10s.
Ammonium chloride, NH_4Cl . . .	26·16	25
Ammonium nitrate, NH_4NO_3 . . .	35·00	36
Ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$. . .	29·16	35

It is therefore evident that the cheapest source of nitrogen in the form of ammonium compounds suitable for agricultural purposes is the sulphate. Ammonia itself is derived from several sources. Those of commercial value may be said to be:—

(1) The gases from the smelting of iron ore with coal in blast furnaces. They contain nitrogen, hydrogen, carbonic oxide, carbonic acid, and ammonia, the proportion of nitrogen varying from 50 to 52 per cent. by volume. The gases are drawn through large perpendicular condensers and scrubbers, in which the ammonia is condensed to form ammoniacal liquor which passes along with the tar, the former separating from the latter through difference in specific gravity. The ammoniacal liquor after separation is distilled with steam, the vapours passing into sulphuric acid for absorption. When completely saturated the sulphate deposits as a grey crystalline powder, which, after draining and exposure to air for two or three days, is ready for manurial purposes.

(2) As a bye-product in the destructive distillation of fuel for illuminating purposes.

The vapours from the gas retorts may be classed as condensable and non-condensable. The non-condensable portion constituting illuminating gas is, after purification, stored in large gasometers for use in lighting our streets. The con-

densable portion, containing the greater part of the nitrogen of the coal carbonised, forms the tar and ammoniacal liquor of the gas works, and from the latter ammonium sulphate is made, as previously described.

The yield of sulphate is considerable. On the average 1 ton of Lancashire coal yields 10,000 cubic feet of gas, and 20 to 25 gallons of ammoniacal liquor at 5° T., this being equal to 30 lb. of sulphate of ammonia.

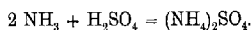
(3) In the carbonisation of small coal for the manufacture of coke for smelting purposes in the Simon-Carves, Semet-Solvay, and other ovens, the condensed gases produce a good return of ammonia.

Westphalian coal (Germany) yields on carbonisation for the production of coke about 14 per cent. of ammoniacal liquor at 4° B., equal to a production of 1 ton of ammonium sulphate per 100 tons of dry coal. An average English coal for coking yields about 22 cwts. per 100 tons of dry coal.

(4) Another supply of ammonia is obtained from the destructive distillation of shale, carried on by the Scotch mineral oil companies. The yield of ammonium sulphate ranges from 16 to 18 cwts. per 100 tons shale treated.

(5) In the carbonisation of bones for the manufacture of animal char, a further supply of ammonia is obtained. This is treated fully under "Animal Charcoal".

Sulphate of ammonia is formed by the combination of gaseous ammonia with sulphuric acid.



Ammonia + sulphuric acid = ammonium sulphate.

The commercial product has a grey colour due to finely divided tarry matter which is disseminated through the mass. Two analyses by the author gave the following results:—

	(1)	(2)
Moisture	3.51	5.72
Sulphate of ammonia ¹	94.87	93.26
Organic matter . . . . .	.85	.54
Mineral matter . . . . .	.77	.48
	<hr/> 100.00	<hr/> 100.00

¹ Equal to ammonia (NH₃) (1) 24.43 per cent.
 (2) 24.02 "

The production of sulphate of ammonia in this country is about 120,000 tons per annum, by far the largest proportion of which is used for agricultural purposes.

The value of sulphate of ammonia naturally depends on the nitrogen it contains and the rapid manner it diffuses itself through and is absorbed by the soil.

Sulphate of ammonia is decomposed by the bacteria in the soil, the nitrogen being converted into nitrates and the sulphuric acid combining with lime or other bases. It exerts a very important influence in the nutrition of plants, nitrogen in a combined form being essential to their growth; for instance wheat, when dry, yields 17 lb. of nitrogen to the ton of cereal, this being equal to the consumption of 80 lb. of sulphate of ammonia. Although beneficial in all soils, it diffuses itself more quickly, and thus acts more readily on light, sandy soils than on heavy, clayey lands. On calcareous soils it is considered equally effective, although it has been urged that the action of the lime constituents of the soil on the sulphate of ammonia results in the formation of volatile carbonate of ammonia or even free ammonia, which thus lessens the fertilising power of the sulphate. Hence the advocacy of sodium nitrate in its place. For all root crops, grass lands, and cereals, sulphate of ammonia has been proved by the most practical authorities to be an invaluable manure; and regarding the experiments on wheat crops carried on by the late Sir J. B. Lawes, Liebig gives his

approval by saying that, "All the experiments of Lawes in England have shown that for 1 lb. of salts of ammonia in manures, 2 lb. of wheat may be reaped".

SODIUM NITRATE.

Sodium nitrate, NaNO_3 , commercially termed Chili salt-petre, is a combination of the metal sodium with nitric acid, the latter providing the nitrogen (16·4 per cent.) on which the value of the saltpetre depends.

The commercial product contains 95 to 97 per cent. of pure nitrate, as may be seen from the following analyses by the author:—

	(1)	(2)
Sodium nitrate . . .	96·39	97·60
„ sulphate . . .	·56	·39
„ chloride . . .	·76	·41
Oxide of iron . . .	·12	Trace
Insoluble matter . . .	·82	·57
Water . . .	1·35	1·03
	<hr/> 100·00	<hr/> 100·00

From the province of Tarapaca in South America is derived by far the major portion of the nitrate used in this country. The crude deposits, or "caliche" as they are called, are found in beds from four to twelve feet in thickness, and are mined in three qualities, the richest averaging 55 per cent. of nitrate of soda. The "caliche" is a mixture of sodium nitrate with chloride and sulphate of soda and sulphates of lime and magnesia, the nitrate being separated by a careful system of lixiviation. The exportation now reaches the enormous figure of 800,000 tons per annum.

Nitrate of soda and sulphate of ammonia are the two chief sources of inorganic nitrogen, both of these being readily soluble, and diffusing with rapidity through the soil. Experiment has, however, shown that on a dry soil the best results are obtained from the use of nitrate.

For many crops nitrate alone, or in conjunction with common salt, forms an excellent manure. With oats, wheat, and barley, the increase of grain by its use is 18 to 19 per cent.

As a top-dressing for turnips, potatoes, peas, and other edible plants, it is unequalled. According to Dr. Slutzer, nitrate of soda does not unduly exhaust the land, and yet by means of it the plant foods are rendered more easily assimilated for nutrition.

About $1\frac{1}{2}$ to 2 cwts. of nitrate of soda per acre, as a top-dressing, is sufficient for most crops.

POTASSIUM NITRATE.

Potassium nitrate, KNO_3 , or the nitre of commerce, is similar in its action to the soda salt, but it contains in addition potassium which is also an essential constituent of plants. The available nitrogen, however, is much less, being 13·8 per cent. in the pure salt.

Potassium nitrate is rarely used for agricultural purposes, as the soda salt is much cheaper and fulfils all the requirements of a nitrate.

The pure salt has the percentage composition—

Potassium	.	.	.	.	38·67
Nitrogen	.	.	.	.	13·86
Oxygen	.	.	.	.	47·47
					<hr/>
					100·00

ORGANIC NITROGENOUS MATTERS.

Organic nitrogenous matters, such as shoddy, ground hoofs and horns, soot, leather waste, dried blood and meat, damaged seed cakes, etc., are also used to a limited extent as nitrogenous manures. The nitrogen in them being in an insoluble form, however, their action on the soil is very slow, and consequently their nutritive value is low. For this reason they can never supplant the soluble ammonia or soda salts as fertilisers.

Shoddy.—Shoddy is a refuse product from the textile

industries, and contains, when dry, about 7 to 8 per cent. of nitrogen. It is not prepared by any chemical treatment, but is spread on the land in its raw state.

Hoofs and Horns.—Hoofs and horns are picked from the raw bones before degreasing, and crushed to a fine powder. In this form they are mixed to a limited extent with superphosphates. They contain 12 to 14 per cent. of nitrogen.

Soot.—Soot is formed by the incomplete combustion of coal, and forms a black carbonaceous mass issuing in the form of smoke from the many chimneys of our industrial centres. That the amount floating in the atmosphere is large may be gathered from the investigations of Dr. Cohen. He estimates that over the four square miles of Leeds 300 cwts. = 1·2 milligrams per cubic foot, are suspended at any particular moment, and that 20 tons of soot pass into the air daily. The effect of this on the growth of vegetation may be gauged when it is remembered that soot contains 2 to 5 per cent. of nitrogen, and that almost all this nitrogen exists as ammonium sulphate, which, on being dissolved by rain, is carried to the soil as a fertiliser.

Soot can be used with good effect on vegetables and cereal crops, and also as a top-dressing. In using it 40 to 45 bushels per acre are advisable. Dr. Griffiths gives the following analysis of a sample of soot:—

Moisture	7·39
Organic matter	43·09
(Containing nitrogen)	0·21
Equal to ammonia	0·25)
Sulphate of ammonia	12·72
Oxides of iron and alumina	6·51
Carbonate of lime	10·63
Carbonate of magnesia	1·84
Alkalies	2·70
Insoluble silica	15·12
	<hr/>
	100·00

Leather Waste.—Leather waste is of little value when applied in its raw state to the soil. Sometimes it is brought into the market in a prepared state. This is done by treating the leather with superheated steam, and drying the mass; by which means the nitrogen is converted into a more soluble condition. Its use is, however, very limited. The percentage of nitrogen averages about 5.

Dried Meat.—This is the residual insoluble matter left during the manufacture of beef extract, dried and powdered. It is not used to any great extent for manurial purposes. When not adulterated with ground bones, the nitrogen averages about 10 per cent.

Dried Blood.—Blood may be considered as the most valuable of all the organic nitrogenous manures. Macadam gives the analysis of raw or natural sheep's blood as follows :—

	Clot.	Liquid.	Whole Blood.
Water	68.156	90.121	87.42
Nitrogenous organic matter ¹ . .	31.491	9.301	11.38
Alkaline salts . .	0.162	0.438	1.20
Phosphates . .	0.073	0.037	
Oxide of iron, etc. .	0.091	0.103	
Carbonate of lime, etc.	0.027		
	<u>100.000</u>	<u>100.000</u>	<u>100.00</u>

¹ Containing nitrogen =
to ammonia . . .

5.811

1.580

1.732

When blood is allowed to stand it quickly coagulates, the corpuscles and fibrin separating as a clotted mass from the serum or watery portion. The coagulated mass or fibrin is separated on the large scale by gravitation or by centrifugal means, and is sold to a limited extent as a manure. The composition of this material is as follows, according to Macadam :—

In 100 parts—

Moisture	30.56
Organic matter ¹	52.43
Alkaline salts	4.52
Phosphates	2.21
Carbonate of lime	4.72
Iron, etc.	2.35
Silica	3.21
	<hr/>
	100.00

¹ Containing nitrogen = to ammonia 7.22

The ash or mineral matter contains in 100 parts:—

Sulphuric acid	81
Phosphoric acid	13.96
Chlorine	20.76
Potassium	41.02
Sodium	12.95
Oxygen	8.21
Phosphate of lime	1.40
Phosphate of magnesia . . . . .	.89
	<hr/>
	100.00

As previously stated, this manure has but a limited sale. It contains a high percentage of water, and rapidly decomposes.

The concentrated or dried blood in the market is a better manure and easier worked.

For the treatment of blood several methods are in use producing a dry, powdery manure, amongst which may be mentioned the addition of a mixture of sulphate of iron and alum; the treating of blood with peat and chalk; the precipitation with alkaline phosphates or sulphates; and Delacharlonny's method of producing a solid manure by means of acid ferric sulphate in the place of the neutral sulphate.

Dried blood contains water 10.56, nitrogenous matter 86.92, and saline matter 2.52 with about 12 per cent. of

nitrogen, and is an effective manure for all plants, more especially for cereals and root crops.

SUPERPHOSPHATES.

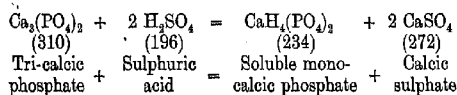
The union of phosphoric acid with calcium results in the formation of three distinct varieties of phosphates :—

- (1) Mono-calcic phosphate, $\text{CaH}_4(\text{PO}_4)_2$.
- (2) Bi-calcic phosphate, $\text{Ca}_2\text{H}_2(\text{PO}_4)_2$.
- (3) Tri-calcic phosphate, $\text{Ca}_3(\text{PO}_4)_2$.

Mono-calcic phosphate is soluble in water, and forms the "soluble phosphate" of the manure-maker. Under certain conditions, the second is the result of the reaction between the soluble and insoluble phosphates of the superphosphates of commerce. It is insoluble in water.

The third is the insoluble phosphate of all the mineral and bone products used in the manufacture of superphosphates.

By acting upon the third or tri-calcic phosphate with sulphuric acid we obtain the first or mono-calcic phosphate and two equivalents of calcic sulphate, forming the superphosphate of commerce. If pure tri-calcic phosphate and sulphuric acid are mixed together according to their combining proportions, we obtain the following reaction :—



310 parts of phosphate require 196 parts of sulphuric acid to combine, forming 234 parts of soluble phosphate (the valuable portion of the manure) and 272 parts of sulphate of calcium or gypsum, which possesses little nutritive value; or, to put it in another way, 1 ton of pure mineral phosphate requires 12·64 cwts. of sulphuric acid, and yields 1·6 tons (1 ton 12 cwts. 2 qrs. 14 lb.) of superphosphates ($\text{CaH}_4(\text{PO}_4)_2$

+ 2CaSO_4 containing 46·24 per cent. of mono-calcic or soluble phosphate.

In practice this high percentage is not attainable, for the reason that the manufacturer does not deal with pure phosphate of lime but with a mineral or bone product, varying in the former case from 45 to 75 per cent. of pure tri-calcic phosphate, and in the latter, 52 to 60 per cent. In mineral phosphates these occur as impurities, carbonate of lime, calcium fluoride, alkaline salts (mainly common salt), and the oxides of iron and alumina. Degelatinised bones contain a considerable proportion of carbonate of lime. All these form sulphates when the mineral or bone is treated with sulphuric acid, which remains with the superphosphate formed, reducing the soluble phosphate to 25 or 30 per cent.

Again, the consumption of acid is very materially increased by their presence, as is seen by the following table, and thus the cost of working becomes greater :—

100 parts of—

Tri-calcic phosphate require	63·2	parts of sulphuric acid
Carbonate of lime	98·0	" " "
Calcium fluoride	125·6	" " "
Alumina	287·7	" " "
Ferric oxide	184·1	" " "

Carbonate of lime, when not in excess, is beneficial, because in addition to forming gypsum, which acts as a dryer to the superphosphate, it also evolves carbonic acid which imparts a certain sponginess and lightness. Calcium fluoride has no value, in fact it is detrimental as the hydro-fluoric gas produced during its decomposition is a nuisance to the mixer. Alumina and ferric oxide are anything but beneficial to the superphosphate, as they act on the "soluble" phosphate, converting it to insoluble phosphates of alumina or iron which is called reversion.

The soluble and insoluble phosphates of bone or char are

of more value than equal percentages in a mineral superphosphate, due to the fact that there is a quicker assimilation into the soil, and necessarily higher fertilising power. Manufacturers generally sell on a basis of 32 to 34 per cent. of soluble phosphates (calculated as tribasic), and 2 to 4 per cent. of insoluble.

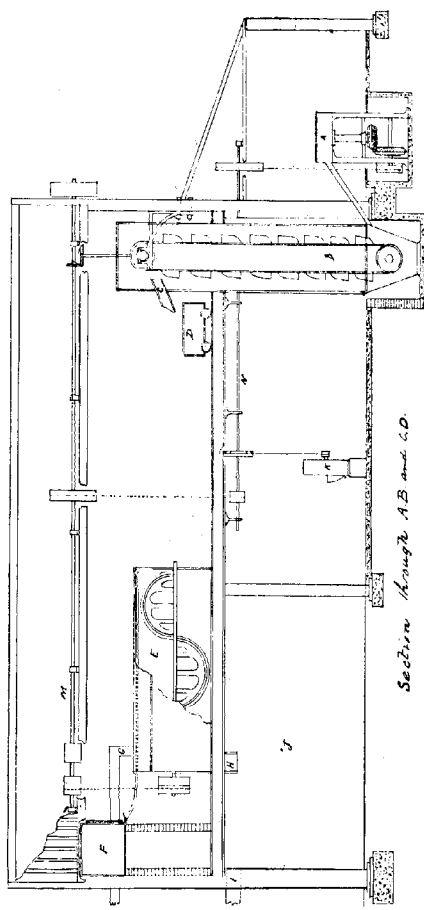
The following represents the composition of three samples of superphosphates analysed by the author, made from—(1) spent char; (2) equal parts of degelatinised bones and mineral phosphates; and (3) mineral phosphates solely:—

	Spent char.	Equal parts of de- gelatinised bones and mineral phosphates.	Mineral phosphates.
Total moisture . . .	12.17	16.39	20.26
Organic matter . . .	11.39	6.45	...
Mono-calcic phosphate ¹ . . .	24.90	24.39	25.58
Tri-calcic phosphate . . .	2.51	4.14	3.07
Sulphate of lime . . .	43.33	40.24	39.68
Ferric and aluminic sulphates . . .	.84	2.23	5.01
Magnesium sulphate . . .	...	.64	1.92
Alkaline sulphates . . .	3.07	1.31	...
Insoluble matter, silica . . .	1.79	4.21	4.48
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>

¹Equivalent to tribasic phosphate of lime . . .

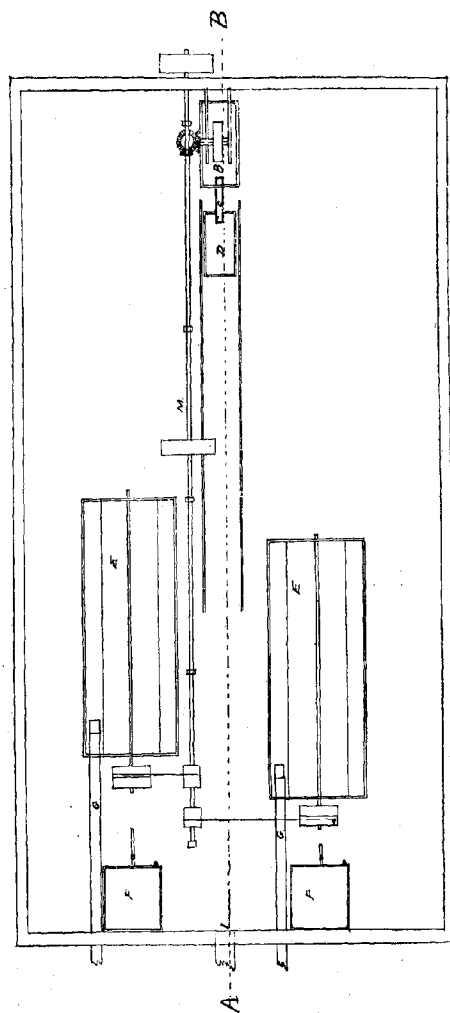
33.00	32.80	33.89
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Degelatinised bones and mineral phosphates require to be ground to meal before elevation to the mixing trough. Bone char or spent char, being in a fine granular condition, requires no preparatory grinding. With mineral phosphates it is essential that a degree of fineness be attained which will enable them to pass through a 50-mesh sieve without any "tailings". The grinding is carried out by a triple set of millstones. In Figs. 11, 12, and 13 are shown the longi-

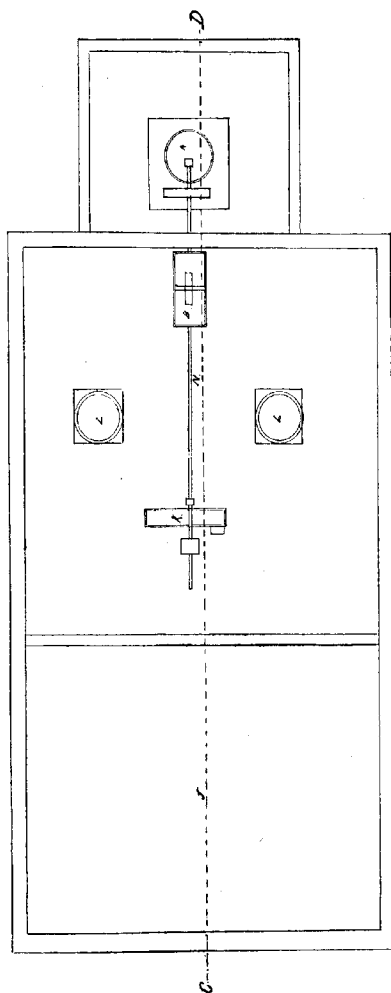


Section through A.B. and C.D.
FIG. 11.—Manure Shed.

Section through A B and C D.



Plan of First Floor
FIG. 12.—Manure Shed.



Plan of Ground Floor.
FIG. 13.—Manure Shed.

tudinal section and upper and ground floor plans respectively of a modern manure-shed measuring 40 feet long by 23 feet high from the floor to the ridge of the roof.

A represents the triple set of millstones fitted up in a lean-to building adjoining the main building, and called the "grinding-house," each set being worked by two bevelled cog-wheels underneath, driven from the shaft *N*. The stones are made of the hardest French "burrs" on edge, and have a diameter of 4 feet 6 inches. They can be regulated to grind to any degree of fineness required. From the millstones the ground materials pass by a "shute" to the "boot" of the elevator *B*, which is fixed vertically and closed the whole length by a wooden cover. It is driven by two cog-wheels from the shaft *M*. The elevator lifts the ground phosphate to the upper floor (Fig. 12), thence falling through the shute *C* to the bogie *D*, by which it is carried to the mixing-trough *E*. The trough is built of stout 2-inch timber, lead-lined, and has a measurement of 12 feet by 5 feet by 5 feet, is bevelled at the top, and fed through a sliding-door fixed on the bevel, from the bogie. Through the centre of the trough runs a shaft carrying the spiral mixer, which is driven from the pulley on the shaft *M*. *F* is a lead-lined tank 3 feet square supported on brick columns. This is intended for holding the sulphuric acid used, the latter being conveyed to the trough by means of a lead pipe, fitted with necessary stop-cock, which runs the length of the mixer, the portion of the pipe within the trough being perforated to allow the acid to spray over the mass.

The tank holds about 168 gallons, and on the outside a scale divided into inches is fixed, each division corresponding to a known weight of acid, thus at a glance the workman can see the number of inches and therefore the weight of the acid used.

During the mixing in the trough, hydrofluoric, carbonic, and other deleterious acid gases are evolved owing to the

chemical action which takes place. These are drawn through the outlet pipe *G*, by an exhaust fan, into condensers and scrubbers, whereby the noxious vapours are removed by solution. In many country works manufacturers do not trouble themselves about the penalties attached to an offence under the Noxious Vapours Act; they do not care to lay out expense in suitable condensing arrangements, consequently the gases, altogether untreated, pass into the works chimney, and vegetation in the neighbourhood naturally suffers.

When the mixing is completed, the sliding-door at *H* is opened, and by the action of the spiral the hot and soft mass is forced from the trough into a large chamber or "den" *J*, as it is termed, placed directly underneath. The "den" is a brick-lined building running the height of the ground floor, it has a length of 16 feet, width 22 feet, and height 9 feet. At the corner *I* is placed an outlet pipe, in connexion with *G*, by which the noxious gases are removed to the condensers.

The front of the den is provided with a large door, through which the superphosphate, after drying and cooling, is conveyed to the disintegrator *K*, driven from the shaft *N*. Here the hard and lumpy material is crushed to a coarse powder, and made ready for mixing with suitable proportions of kainite, ammoniacal salts, dried blood, or other nitrogenous matters, to form the "artificial" for cereal, root, grass, or other crops. This is done by spreading out the coarse superphosphate, adding the necessary ingredients in the proportions required, turning the heap over once or twice, and finally passing through the mixers *LL*, as shown in Fig. 13—the manure being then ready for bagging.

In gauging the amount of acid required the manufacturer must consider its strength, and also the nature of the phosphate he is dealing with. A phosphate containing a low proportion of lime over the quantity required to form tri-calcium phosphate, that is to say very little carbonate, or fluoride of calcium, with but a small percentage of iron or

alumina, consumes less acid and yields a richer superphosphate; on the other hand, if the excess of lime should be considerable, and the proportions of alumina and oxide of iron also high, the consumption of acid will be greater and a weaker superphosphate will be the result. From the table previously given, it will be noticed that while 100 parts of tricalcium phosphate require for conversion 63 parts of acid, 100 parts of carbonate of lime consume 98 parts, calcium fluoride 125 parts, or nearly double, and oxide of iron and alumina 184 and 288 parts respectively. Consequently the purer the phosphate the more economically can it be worked, and the richer the superphosphate produced.

For mixing purposes the most suitable acid has been found to be the quality described as "chamber acid,"¹ having a specific gravity of 1.57, equal to a strength of 114° Twaddell. Acid of this strength contains 65 per cent. of anhydrous sulphuric acid and 35 per cent. of water. A portion of the latter is given off as steam, owing to the chemical action in the trough generating a high temperature; the remainder unites with the sulphate of lime to form a hydrate, thus drying the superphosphate.

A charge of 8 to 9 cwts. of ground phosphate is allowed to each trough, the conversion on the addition of the acid taking about eight minutes. Each trough, then, of the dimensions given will produce from 6 to 7 tons of superphosphates per hour, or, in a working day of ten hours, 60 to 70 tons, which is ready for removal every alternate day from the den below.

The following represent a few of the mixings for superphosphate:—

High-Class Superphosphates.

	Cwts.	Qrs.	Lb.
Acid (spec. grav., 1.57)	4	2	16
Spent char	3	0	0
New char siftings	3	0	0

¹ This is acid taken direct from the lead chambers.

Special Black Superphosphates.

	Cwts.	Qrs.	Lb.
Char siftings	6	0	0
Acid (spec. grav., 1.57)	4	3	8

Bone Superphosphates.

	Cwts.	Qrs.	Lb.
Acid (spec. grav., 1.57)	6	0	0
Degelatinised bones, and spent char	7	2	0

Mineral Superphosphates.

	Cwts.	Qrs.	Lb.
Acid (spec. grav., 1.57)	7	1	12
Mineral phosphates	8	0	0

Taking the average of mineral phosphates, the consumption of acid is about 92 per cent. of the weight of phosphate taken.

Superphosphates supply lime, sulphuric and phosphoric acids to the soil. The phosphoric acid, with which is combined lime in the form of mono-calcic phosphate, is quickly absorbed by the rootlets of the plant. The remainder of the lime is in combination with sulphuric acid as sulphate of lime, which changes but slowly, by bacterial decomposition in the soil, before it yields its nutritive constituents.

Although forming valuable manures for all grain and root crops, superphosphates are not often used alone, but rather in conjunction with certain proportions of potash and ammonium salts, forming the mixed or special manures compounded to suit the requirements of various crops.

SPECIAL OR MIXED MANURES.

Although the ashes of plants consist of many mineral ingredients, yet it is safe to conclude that they depend for their existence more particularly on the potash, phosphoric acid, and nitrogen abstracted from the soil, these varying in the amount absorbed according to the class of plant. For

instance, nitrogen is the most important nutritive required by wheat, oats, rye, grass, and other plants; with beans, clover, potatoes, etc., potash is specially needed; while for maize, turnips, and other crops, phosphates are the main food absorbed, along with potash and ammonia. With this knowledge, the maker is in a position to compound a manure suitable for any desired crop.

All special manures are sold to the farmer on guarantees, in conformity with the strength of manure manufactured, and, with a knowledge of the unit values of potash, nitrogen, and phosphoric acid, he can readily estimate their value and judge whether he is overcharged. With manure manufacturers of standing, adulteration is not practised, therefore their guarantee may be depended upon to represent the average of the bulk to be supplied.

The following are the leading "artificial" made, with their guarantees of strength:—

(1) *Special early Potato Manure.*

Sulphate of potash	. . .	3 to 5 per cent.
Soluble phosphates	. . .	20 to 22 "
Insoluble phosphates	. . .	2 to 4 "
Ammonia	. . .	10 to 11 "

(2) *Special Potato Manure.*

Sulphate of potash	. . .	8 to 10 per cent.
Soluble phosphates	. . .	22 to 24 "
Insoluble phosphates	. . .	1 to 2 "
Ammonia	. . .	3½ to 3¾ "

The mixings per ton being—

Superphosphates	. . .	12½ cwt.
Kainite	. . .	5½ "
Sulphate of ammonia	. . .	2 "

The manure being applied in the proportion of 5 to 6 cwt. per acre.

Special Manure for Turnips, Mangels, etc.

Sulphate of potash . . .	3 to 4 per cent.
Soluble phosphates . . .	26 to 28 „
Insoluble phosphates . . .	2 to 4 „
Ammonia	3 to 4 „

The mixings per ton being—

Superphosphates	15 cwt.
Kainite	3 „
Sulphate of ammonia	2 „

The quantities used being 5 cwt. per acre.

A good manure for mangels, turnips, etc., should contain 30 to 32 per cent. of total phosphates, with 26 to 28 per cent. soluble, and appreciable proportions of potash and ammonia. The manure is spread broadcast after seed-time, and then covered in.

Dissolved Bones.—The following is a good strength for this manure:—

Soluble phosphates . . .	21 to 23 per cent.
Insoluble phosphates . . .	10 to 12 „
Ammonia	3 to 3½ „

This manure is generally made from degreased bones (not boiled), by treating them, in a crushed state, with sulphuric acid. The mass is then mixed with a small proportion of bone dust to dry up the manure, allowed to harden, one to two days; then passed through the disintegrator to break up any lumps, and bagged in the usual way. The bones not being degelatinised, furnish the nitrogen without any addition of ammoniacal salts.

Dissolved bones made from degelatinised bones (bones with the gelatine boiled out) contain more phosphate, but are much poorer in nitrogen, which does not exceed 1 per cent. in a well-degelatinised bone; if made from raw bones, or bones that have been treated by the benzene process to remove the fat only, then the nitrogen in the bone is retained. This

difference in nitrogen in a manure from raw or degreased bones, or from degelatinised or steamed bones, makes a considerable difference in the value. Dissolved bones should be bought on the percentages of soluble and insoluble phosphates and ammonia present.

Dissolved bones form a useful all-round manure, being of advantage to nearly all crops. It is best used in early spring, in quantities of about 5 cwts. to the acre of root or grass crops.

Dissolved Bone Compound.

Soluble phosphates . . .	20 to 21 per cent.
Insoluble phosphates . . .	6 to 7 „
Ammonia	2 to 2½ „

This manure is all bone, and is generally made from degelatinised bones (bones with the gelatine boiled out) and sulphuric acid; the deficiency in nitrogen is made up by intimately mixing in the required amount of nitrogen in the form of sulphate of ammonia. (132 parts of the salt contain 28 parts of nitrogen.)

The manure is not so strong in phosphates and ammonia as that made from raw or degreased bones, consequently it is cheaper. It has been found of special importance "on cold, clayey, and also still calcareous or damp soils". For promoting the early maturity of turnips, mangels, and other root crops, this manure is very efficacious and economical. The proportions are about 4 cwts. to an acre, to be applied at seed-time.

Dissolved Peruvian Guano.—In this form guanos are more suitable and economical to the farmer, being quicker in manurial action than raw guanos, and with no loss of valuable ammonia.

A good strength dissolved guano contains the following:—

Total phosphates . . .	23 per cent.
Soluble phosphates . . .	21½ „
Insoluble phosphates . . .	1½ „
Ammonia	9 „

The guarantee is given on the phosphates and ammonia, not on potash or alkaline salts, unless specially required.

This dissolved manure is prepared by treating Peruvian guano with 80 to 82 per cent. of its weight of sulphuric acid in the manure trough, cooling in the "den," and passing through the disintegrator to reduce it to a granular condition. The chemical action of the acid results in the fixation of the volatile ammonia as sulphate; at the same time the tri-calcic phosphate is converted into the soluble or mono-calcic phosphate, and the manure is left in a dry and granular condition of good strength, suitable for the drill.

Enriched Peruvian Guano.—This manure is sold on the following basis:—

Guano phosphates	. . .	41 to 43 per cent.
Ammonia	. . .	10 "
Sulphate of potash	. . .	1 to 1½ "

Enriched Peruvian guano is Peruvian guano of medium quality, fortified with sulphate of ammonia, to form a high strength Peruvian guano.

The manure can be applied to all soils not of a calcareous or chalky nature.

Special Manure for Garden Stuffs, Carrots, Cabbages, Beetroots, etc.—The following mixing forms an excellent manure for garden stuffs:—

	Per ton of manure.
Superphosphates	. . . 13 cwt.
Sulphate of ammonia	. . . 4½ "
Kainite	. . . 2½ "

—the whole intimately mixed together and applied in the proportion of 6 to 6½ cwt. per acre.

Special Manures for Grass Lands.—The following quantities per ton form a nourishing manure when sown on the land. It is recognised that nitrogenous manures increase the

quantity, while phosphatic manures, and those containing potash, improve the quality of the herbage.

Superphosphates	11 cwt.
Kainite	5 „
Sulphate of ammonia	4 „

These ingredients are intimately mixed together, and applied at the rate of 11 to 12 cwt. per acre.

Special Tobacco Manures.—Considerable quantities of manures are now made and sent abroad for use in the cultivation of tobacco crops. The essential ingredients for the growth of the tobacco plant are phosphates, nitrogen, and potash, these being compounded on the following basis :—

Soluble phosphates	18½ to 19½ per cent.
Insoluble phosphates	16 to 17 „
Sulphate of potash	10 „
Ammonia	5 to 6 „

The whole of the phosphates are derived from Peruvian guano, together with part of the ammonia and potash; the remainder is made up by admixture with the sulphates of potash and ammonia in the required proportions. Below is an analysis of special tobacco guano, as used by the British Deli Co., Belewau :—

Ammonia salts ¹	10·38
Organic matter ²	12·34
Mono-calcic phosphate ³	14·25
Insoluble guano phosphate	16·81
Alkaline salts ⁴	10·94
Hydrated calcium sulphate, magnesia, salts, etc.	25·89
Moisture	8·21
Insoluble silicious matter	1·18

100·00

¹ Containing active soluble ammonia	2·67
² Containing organic assimilable ammonia	2·64
Total ammonia	5·31
³ Equivalent to tribasic phosphate of lime	18·86
Insoluble guano phosphates	16·81
⁴ Containing sulphate of potash	10·54

Special Sugar-Cane Manure.—This manure is generally prepared from spent char, and with the following strength:—

Soluble phosphates . . .	19 to 20	per cent.
Insoluble phosphates . . .	3½ to 4½	„
Potassium sulphate . . .	9	„
Ammonia . . .	10 to 11	„

Sulphate of ammonia has been used for enriching the juice of the cane, but this fertiliser can only act with advantage when the soil contains the necessary amounts of lime and magnesia. In using a manure containing lime in a combined state, any deficiency of this ingredient in the soil is restored by the decomposition of the calcium phosphate and calcium sulphate which form part of the manure.

It has been urged that the farmer should compound his own manures instead of buying them in a mixed state. The suggestion is not an impracticable one, for, having a knowledge of the nutritive requirements of each crop, and the source from which these nutritives can be obtained, it requires no great skill for the farmer to prepare a manure of any desired strength, at considerably less cost than would be the case if bought ready mixed.

A manure is not a chemical combination, but is simply a mechanical mixture of certain ingredients required to suit a particular crop, the weighing and mixing of these ingredients can therefore be done as well on the farm as at the manure works. The mixing, however, must be carried on in a dry shed, and the material can be bagged for use at any season.

Suppose the farmer wishes to make a manure of the following strength:—

Soluble and insoluble phosphates . . .	13	per cent.
Sulphate of potash . . .	4	„
Ammonia . . .	10	„

The phosphates would be bought as superphosphates, the sulphate of potash as kainite, and the ammonia as sulphate of ammonia.

The proportions of these ingredients to use for 5 tons (100 cwt.) would be as follows:—

Superphosphate contains say 36 per cent. phosphates, 33 soluble and 3 insoluble, therefore

$$13 \times \frac{100}{36} = 36 \text{ cwt.}$$

Kainite contains 25 per cent. of sulphate of potash, therefore

$$4 \times \frac{100}{25} = 16 \text{ cwt. of kainite.}$$

Sulphate of ammonia contains 21 per cent. of ammonia, therefore

$$10 \times \frac{100}{21} = 48 \text{ cwt. of sulphate of ammonia.}$$

The cost of this fertilizer can be calculated as follows:—

36 cwt. of superphosphate at £3 per ton	£5 8 0
16 cwt. of kainite at £2 10s. per ton	2 0 0
48 cwt. of sulphate of ammonia at £13 10s. per ton	32 8 0
	<hr/>
	£39 16 0

£39 16s. ÷ 5 = £7 19s. 2d. per ton.

VALUATION OF MANURES.

Chemical analysis defines only the composition of a manure. In determining the commercial value, we have to inquire concerning the origin of its constituents—that is, we must find whether the phosphates are from bone or from a mineral source, and if the nitrogen exists as a soluble ammonia salt or is derived from nitrogenous matter. These are necessary inquiries, for bone phosphates have a higher

agricultural value than mineral phosphates of equal strength, and the nitrogen of sulphate of ammonia is worth considerably more than the same element, derived from treated leather waste or dried blood. Superphosphates are bought on the amount of soluble phosphate they contain. By this is understood not the actual amount of mono-calcic phosphate which constitutes the soluble part of the manure, but its equivalent of tribasic phosphate of lime which is rendered soluble by the acid treatment.

The value of fertilizers is regulated by the amount of useful constituents—potash, phosphoric acid and nitrogen (or ammonia)—which they contain, and also by the market price of the raw materials. Taking an analysis of a fertilizer, the percentage numbers are termed units and each unit has a certain value according to the source from which it is derived. For instance the present price of mineral superphosphate containing 35 per cent. of soluble phosphate is 60s. per ton. Therefore each per cent. or unit of phosphate in the soluble form has a value of $\frac{60}{35} = 1\text{s. } 8\text{d.}$

In the insoluble state the value of the phosphate is only 8d. per unit, while in a superphosphate made from bones the unit may be worth 2s. 6d. or 3s.

The value of the unit of ammonia in sulphate of ammonia at the present price = 12s. 10d., but the same equivalent of nitrogen in nitrogenous organic matter calculated as ammonia is worth only 8s. Sulphate of potash in kainite is at present worth 2s. per unit.

Suppose that a fertilizer contains the following:—

20	per cent.	of soluble phosphates,
4	„	insoluble phosphates,
10	„	sulphate of potash,
3½	„	ammonia (as sulphate),

then its value can be calculated as follows:—

Constituent.	No. of units.	Price per unit.	Value per ton.
Soluble phosphate	. 20 ×	1s. 8d. =	33s. 4d.
Insoluble phosphate	. 4 ×	8d. =	2s. 8d.
Sulphate of potash	. 10 ×	2s. 0d. =	20s. 0d.
Ammonia . . . .	. 3½ ×	12s. 10d. =	44s. 11d.
			<hr/> 100s. 11d. <hr/>

Value = £5 0s. 11d. per ton.

PART III.

CHAPTER IX.

ANALYSIS OF RAW AND FINISHED PRODUCTS.

THIS chapter is devoted to a description of the methods of analyses required in the laboratory of a bone works. The details are given as completely as possible, for the guidance of chemists undertaking this important work—the accuracy of the analyses being a matter of great importance to the manufacturer in successfully carrying on the industry. The raw material entering the works is first considered.

(1) COMMON RAW BONES.

Although not bought on any guarantee, the chemist will find it necessary to make frequent examination of these. The analysis is confined to determination of the moisture, fat, and nitrogen, the results of the latter giving an approximate idea of the ultimate yield of glue. For this purpose a carefully drawn average of the day's intake is made, comprising ribs, jaws, shoulder-blades, heads, etc. These are coarsely broken, and then passed through a small mill, which reduces the whole to a fine state suitable for analysis; after intimately mixing together, an 8 oz. stoppered bottle is filled; from this is rapidly weighed out, to prevent any loss of moisture, the amount required for each determination.

(a) *Moisture*.—5 grams are weighed in a porcelain crucible and heated in the air oven at a temperature of 100° C., cooled

in the desiccator, and reweighed. This is repeated till constant. The difference in weight represents the moisture, and the percentage is calculated as follows:—

Example—

Weight of crucible + bones before heating	. 18.164 grams.
" " after heating	. 17.103 "
Moisture lost	. <u>1.061</u> "

On the 5 grams of sample taken the percentage is—

$$\frac{1.061 \times 100}{5} = 21.22$$

(b) *Fat*.—The fat is determined in a Soxhlet's fat extraction apparatus, shown in Fig. 14. The apparatus comprises

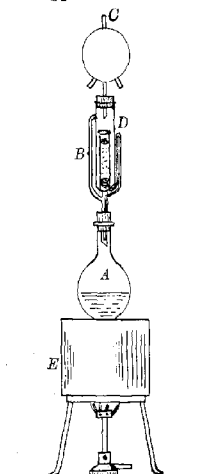


FIG. 14.—Soxhlet Apparatus for Extraction.

a small flask *A*, extractor *B*, condenser *C*, tube *D*, with an opening at the bottom, which is covered with a layer of fine asbestos or glass wool, to prevent any bone particles passing through. The joints are made with good ordinary corks as rubber is affected by ether. The tube is first weighed, then filled three parts full with the sample, and reweighed. The difference is the quantity of the sample taken. It is then inserted in the extractor. The small flask, which must be thoroughly dry, is now tared, and the weight noted. The solvent used is ether, which is carefully poured in at the top of the condenser until the flask is about half full, and heat is then applied by means of a Bunsen flame to the water bath *E*, on which the flask is placed. As the water becomes gradually heated, distillation commences, the ether vapour passing up

through the wide limb of the extractor into the condenser, from the inner tube of which it drips on to the bones within the tube, dissolving out the fatty matter. When the syphon overflow is reached, the ether carrying the fat in solution syphons off into the flask below, the ether being again and again distilled, leaving the fat behind in the flask. This is continued for three hours, when the bones may be safely considered free from fatty matter. The flask is now disconnected, and the ether distilled off through an ordinary condenser, the flask is then wiped with a dry cloth, heated in the air oven for three hours, at a temperature of 100° to 105° C., then cooled, and weighed. This is repeated at intervals of one hour till the weight is constant. The increase of weight is the fat extracted, from which the percentage is calculated.

If the bones are wet a dried portion should be taken for estimation of the fat.

Example—

Tube + sample	. . .	16.189 grams.
Weight of tube alone	. . .	9.432 „
		<hr/>
Sample taken	. . .	6.757 „
Weight of flask + fat	. . .	32.243 „
Weight of flask	. . .	31.399 „
		<hr/>
Fat extracted	. . .	.844 gram.

$$\text{Then } \frac{.844 \times 100}{6.757} = 12.49 \text{ per cent. of fat in the sample.}$$

A check on the percentages of fat and moisture so obtained can be made by drying the tube containing the degreased bones for fourteen hours at 100° to 105° C. and reweighing; the loss of weight represents the combined fat and moisture, from which the percentage can be readily calculated, and should equal the sum of the two results above found.

(c) *Nitrogen*.—The nitrogen is determined by Kjeldahl's process. By this method the organic matter is oxidised, the

nitrogen which it contains being converted into ammonia, which is fixed as sulphate of ammonia by the sulphuric acid present. For analysis, 2 grams of the sample are weighed into a Jena glass flask, and 25 c.c. of strong sulphuric acid added, along with 10 grams of pure potassium sulphate. The whole is gradually heated on a sandbath at first, until frothing ceases, then more strongly on wire gauze, till the black carbon-

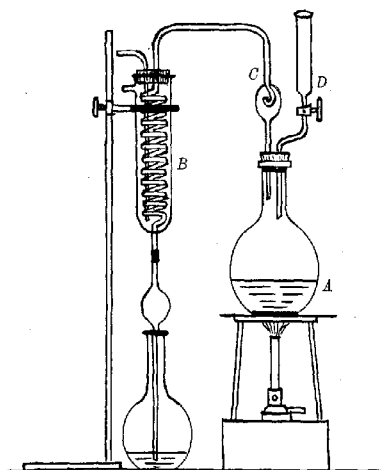


FIG. 15.—Estimation of Nitrogen by Kjeldahl's Process. Apparatus for Distillation of Ammonia.

aceous mass gives place to a clear, pale yellow liquid. This will occupy about three hours. The flask is removed, cooled, and the contents cautiously washed into a larger flask, for distillation. In Fig. 15 is seen a sketch of the apparatus required to distil over the ammonia formed in Kjeldahl's process. The large flask *A* is connected to a condenser *B* by means of the tube *C*, the lower end of the condenser tube ending in a bulb tube dipping under a layer of standard

sulphuric acid, *D* is a funnel, with stopcock, for conveying a solution of caustic soda to the flask. The standard solutions required are sulphuric acid and caustic soda, the former of normal, the latter of decinormal strength. They are prepared in the usual way: 10 c.c. of normal acid are placed in the receiver; a few pieces of sheet zinc are added to the liquid in the distillation flask, the different parts of the apparatus are connected and made tight, then 70 c.c. of a 50 per cent. caustic soda solution are allowed to flow into the flask. Heat is then cautiously applied, the safety tube preventing any risk of caustic soda being mechanically carried over. After gently boiling for about an hour, the whole of the ammonia will be driven over into the receiver, and there absorbed by the sulphuric acid. The receiver is now disconnected, the bulb-tube washed with water, the washings being added to the acid in the receiver, and the whole contents are then diluted to 250 c.c., and 50 c.c. titrated with standard soda solution, according to the well-known volumetric method.

Example—

Weight of sample taken	2 grams.
Normal acid used	10 c.c.
Titration with decinormal caustic soda	$7 \times 5 = 35$ c.c.
Leaving	<u>65 c.c.</u>

Then $65 \times .0014 = .091$, the amount of nitrogen contained in the 2 grams of the sample, the percentage being $\frac{.091 \times 100}{2} = 4.55$.

For practical purposes, 1 part of nitrogen represents 5.4 parts of glue, therefore $5.4 \times 4.55 = 24.57$, the percentage of glue corresponding to the above amount of nitrogen.

The manufacturer, naturally, calculates his yield of glue on the bones passed over a weighing machine, and not on the dry sample.

(2) DEGREASED BONES.

These are examined daily for any fat left unextracted by the naphtha treatment. This is estimated in the Soxhlet apparatus, as described at (1) (b). The unrecovered fat should not exceed .5 per cent.

(3) CRUDE OR UNCLARIFIED FAT.

This is examined for any residual naphtha left in the fat after leaving the mont-jus. The method is described under "Refined Fat".

(4) REFINED FAT.

The analysis of the refined fat is a criterion of its value to the consumer. For this purpose it is necessary to estimate the moisture, organic matter other than fat, ash or mineral matter, solidifying point of the fatty acids (Titer) and free fatty acids. The analysis may be extended to the de-

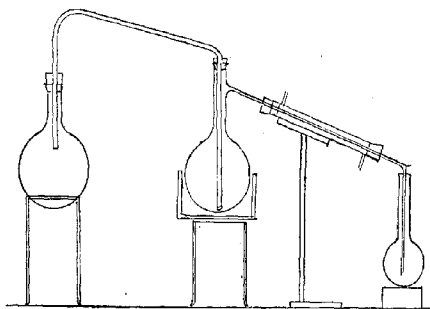


FIG. 16.—Apparatus for Extraction of Benzene from Bone Fat.

termination of the saponification equivalent, and iodine absorption of the fat, but for practical purposes the above are sufficient for the maker.

(a) *Moisture*.—This is determined by heating 50 grams in an open dish on the sand bath, stirring till bubbles cease

to rise. If the fat contains naphtha some of this will pass off with the water. On melting the fat, if it is clear and there is no deposit, water is absent. A trace of water yields a turbidity while a larger quantity will separate to form a layer below the fat.

(b) *Naphtha*.—In estimating the naphtha, 100 grams are taken and placed in a fractional distillation flask with side tube connected to a small Liebig's condenser; to the other end of the latter is fixed, by means of rubber tubing, a bent glass tube, passing into a receiver with a long and narrow neck, graduated into $\frac{1}{10}$ c.c.'s which is half filled with water. The flask is closed with a cork fitted with a glass tube which passes into the fat, the tube being connected with a flask for generating a current of steam. A clip is used for closing the connection between the two flasks; the flask containing the fat is partly embedded in sand on a sand bath, which is heated by means of a Bunsen burner below. (See Fig. 16.) The heat is first raised to about 165° C., then the clip is opened, and a current of steam blown through the liquid fat for half an hour; this dispels the last trace of naphtha. The vapours are condensed to a liquid in their passage through the condenser to the receiver, and in the latter will be found any naphtha present, floating as a thin film on the surface of the water. The receiver is now removed and filled with tepid water to about half-way up the graduated neck, then cooled to the normal temperature, and the naphtha read off on the scale.

Example:—

Suppose the reading was $\cdot 2$ c.c.

Then $\cdot 2 \times \cdot 730$ (specific gravity) = $\cdot 146$ grams naphtha, which on 100 grams of the sample taken would be $\cdot 146$ per cent.

(c) *Ash or Mineral Matter*.—About two grams of the sample are slowly incinerated in a weighed porcelain crucible, great care being taken that no loss occurs by spurting. After

reducing the fat to a black carbonaceous mass by gentle burning, the crucible is removed to a muffle, and heated at a red heat until the ash is left; this burns off the whole of the carbon, leaving as a residue the mineral matter. After cooling and weighing, the calculation is made as follows:—

Example—

Weight of crucible + ash	12.641 grams.
Weight of crucible	12.638 „
	<hr/>
Ash	.003 gram

Therefore 2 grams being taken, the percentage is—

$$\frac{.003 \times 100}{2} = .150$$

(d) *Organic Matter other than Fat.*—This comprises any gelatinous matter abstracted from the bones by careless working, dirt of an organic nature, etc. Take 3 grams of the sample, place in a small beaker, and add carbon disulphide, stir well for a few minutes, then pass on to a tared filter-paper, wash with small portions of carbon disulphide until the filtrate shows no trace of fat, which is known when a drop or two of the filtrate warmed on a watch glass leaves no residue. The filter paper is now dried in the oven, at 100° C. for three or four hours, cooled under a desiccator, and reweighed. The difference represents the organic and mineral impurities.

Example:—

Filter paper + residue . . . . .	.660 gram.
Tare of filter paper . . . . .	.652 „
	<hr/>
Residue	.008 „

Then $\frac{.008 \times 100}{3} = .266$ per cent. of mineral and organic impurity in the sample.

Deducting the mineral matter (ash) previously found (.266 - .150), we obtain .116 as the percentage of organic matter, other than fat, in the sample taken.

(e) *Free Fatty Acids*.—In determining the fatty acids, it is unnecessary to effect an actual separation, the titration being done direct by a standard solution of caustic soda. The solution is made decinormal by dissolving about 4 grams of pure caustic soda in water, and making to a litre. This is standardised by a decinormal solution of sulphuric acid, the strength being adjusted so that 1 c.c. exactly neutralises 0.284 grams of stearic acid. The methylated spirit used must be entirely free from any trace of acid which is insured by previous neutralisation. Five grams of the sample are weighed into a flask, then 70 c.c. of methylated spirit, the mixture is shaken well, and brought to the boil by immersing the flask in boiling water. When the fatty acids are dissolved, a few drops of an alcoholic solution of phenol-phthalein are added, and the decinormal solution of caustic soda run in gradually from a burette until the characteristic pink tint is obtained, indicating that the fatty acids have been completely neutralised.

Example:—

1 c.c. standard solution = 0.0284 grams stearic acid, therefore supposing 50 c.c. are required to effect complete neutralisation of the fatty acids, then $50 \times 0.0284 = 1.420$ grams of free fatty acids in the sample, and the percentage will be $\frac{1.420 \times 100}{5} = 28.40$.

The solidifying point of the fatty acids (Titer) is determined by saponification, liberating the whole of the acids from the soap, and noting the temperature at which they commence to solidify.

(5) DEGELATINISED BONES.

According to the object the manufacturer has in view, these are either partially or wholly degelatinised. If the latter, then they are solely used for manurial purposes; if the former, they undergo carbonisation for animal charcoal.

(aa) *For artificial manures.*—The nitrogen is estimated, indicating the glue unextracted, and phosphates for the manurial value.

(bb) *For animal charcoal.*—The test is confined to determination of organic matter, as a guide to the carbon in the carbonised bone.

The analyses are made on samples dried at 100° C.

(a) *Nitrogen.*—This is determined by Kjeldahl's method as described at (1) (c).

(b) *Phosphates.*—The method is described under "Manures".

(c) *Organic Matter.*—3 grams of the dried sample in a finely divided condition are weighed in a porcelain crucible, which is placed in a muffle, and heated at a bright red heat until the ash is white or pink; on removal of the crucible and cooling, the ash formed is moistened with a few drops of ammonium carbonate solution, dried in the air oven at 150° C. and weighed. The loss of weight represents the organic matter, the percentage being calculated according to the example.

Example—

Crucible + sample, before ignition . . . 16.144 grams.

Crucible + ash, after ignition . . . 15.700 „

Loss of weight (organic matter)444 gram.

Then 3 grams being taken the percentage

is $\frac{.444 \times 100}{3} = 14.80$ per cent.

The ash or mineral matter is the difference between this and the original weight.

(6) ANIMAL CHARCOAL.

(a) *Moisture.*—This is determined as described at (1) (a). The limit allowed being 8 per cent.

(b) *Carbon*.—The sample is finely pulverised, dried at 100° C. for several hours, and 2 grams weighed out for the analysis. It is treated with hydrochloric acid, and heated for one hour at 80° C., then filtered through a tared filter-paper, the residue and paper being well washed with hot water until a portion of the filtrate gives no precipitate with nitrate of silver. The filter paper is then dried and reweighed. The increase of weight is the undissolved carbon and silicious matter. The filter-paper, with its contents, is now carefully folded into a small bulk, placed in a weighed crucible, and ignited in a muffle at a bright red heat; the carbon by this means is burnt to carbonic acid, leaving as a residue the silica or sand. The crucible is cooled in a desiccator and reweighed.

Example—

Filter-paper + residue (carbon and silica)	1.213 grams.
Weight of filter-paper . . . . .	.852 gram.
Residue	<u>.361</u> „

Then if 3 grams are taken—

$$\frac{.361 \times 100}{3} = 12.03 \text{ per cent. of residual matter, carbon, and silica.}$$

Weight of crucible + silica + ash (filter-

paper) after ignition	16.112 grams.
Tare of crucible	16.062 „
	<u>.050</u> gram.
Less ash of filter-paper . . . . .	.003 „
Leaves silica	<u>.047</u> „

The calculation to percentage is—

$$\frac{.047 \times 100}{3} = 1.566 \text{ as the yield of silica.}$$

Then $12.03 - 1.566 = 10.464$ the percentage of carbon in the charcoal.

(7) BONE SUPERPHOSPHATES AND MIXED MANURES.

Under this heading, we shall refer to the principal special

or finished manures, in which bone superphosphate forms the chief ingredient, also mineral phosphates and nitrogenous matters which are used as admixtures in such manures.

As the manures are sold on a basis of the soluble and insoluble phosphates, potash, and ammonia they contain, the work of the chemist is mainly devoted to estimating these constituents. We shall therefore confine ourselves to their separation and estimation.

Sampling.—In sampling from a heap of manure, great care should be taken to get an average of the whole. For this purpose take eight or nine handfuls from the heap and mix well together on a sheet of paper, breaking down any lumps present. Then fill two perfectly dry 6-oz. bottles. One of these is used for analysis, the other being sealed and put away for future reference, if any dispute should arise.

Raw materials, such as rock phosphates, etc., are ground to a powder, which is passed through a 60-mesh riddle, any portion retained by the riddle being again ground until fine enough to pass through the mesh.

(a) *Superphosphates.*—Superphosphates, as made from degelatinised bones, contain very little nitrogen, which, if required, is determined by Kjeldahl's method. The manure is valued on the soluble and insoluble phosphates it contains, the determination being as follows: A portion of the sample is ground in an agate mortar to a fine state of division, and 5 grams weighed. This is transferred to a porcelain mortar, and triturated with water, to dissolve the soluble phosphate, the liquor being passed through a filter into a litre flask. The trituration with water is repeated some four times, the contents of the mortar being then washed on to the filter; the residue on the filter is washed with cold water until the litre flask is about three-fourths full. On the filter is the insoluble, and in the filtrate the soluble phosphate. The flask is filled to the mark with cold water at 15.5° C., and 100 c.c. measured

out (= .5 gram of the sample); in this is estimated the soluble phosphate, either by the citro-magnesia or molybdc method. Both give very accurate results with careful manipulation. The writer, however, from his experience, prefers the former process. To prepare the ammonio-citrate of magnesia required, 270 grams of citric acid are dissolved in hot water, and 27 grams carbonate of magnesia slowly added. The considerable effervescence produced, is due to the liberation of carbonic acid. The solution is further heated until the gas is driven off, then filtered into a litre flask, cooled, and 400 c.c. of a 10 per cent. solution of ammonia added, the whole being made to a litre at 15.5° C. with water. This forms the precipitating medium. The 100 c.c. containing the soluble phosphate are placed in a beaker, ammonia added until faintly alkaline, any precipitate of phosphate of lime formed being dissolved by cautious addition of citric acid, and 60 c.c. of ammonio-citrate of magnesia added. The precipitate of ammonic-magnesian phosphate is slow in appearing, but is hastened by stirring for a few minutes. After standing for six to seven hours in the cold it is filtered, and then washed with a 2 per cent. solution of ammonia until the filtrate gives no precipitate with phosphate of soda. Dry, ignite, and weigh as magnesium pyrophosphate ($\text{Mg}_2\text{P}_2\text{O}_7$).

The calculation is as follows:—

Crucible + $\text{Mg}_2\text{P}_2\text{O}_7$ + ash (filter-paper)	. . .	18.1490	grams.
Tare of crucible	. . .	18.0290	„
		<u>.1200</u>	gram.
Less ash	. . .	.0035	„
Weight of $\text{Mg}_2\text{P}_2\text{O}_7$ found	. . .	<u>.1165</u>	„

The factor for conversion of $\text{Mg}_2\text{P}_2\text{O}_7$ into tri-calcium phosphate $\text{Ca}_3(\text{PO}_4)_2$ is 1.3932.

Then $1165 \times 1.3932 = .1623$ gram as the weight of tri-calcium phosphate in the 100 c.c. (.5 of the sample), or, in the 5 grams taken,

$$.1623 \times 10 = 1.623 \text{ grams,}$$

$$\text{the percentage being } \frac{1.623 \times 100}{5} = 32.46$$

(b) *Insoluble Phosphate*.—The residue on the filter, after washing out the soluble phosphate, is heated for half an hour with strong hydrochloric acid, and then evaporated to dryness on the sand bath, to render the silica insoluble; a few drops of strong hydrochloric acid to moisten the residue, then a little water, and the whole heated for a few minutes, and filtered. The filtrate containing the phosphate is made faintly alkaline with ammonia and the ammonio-citrate of magnesia added, the precipitate of ammonio-magnesium phosphate washed with a 2 per cent. solution of ammonia, dried, ignited, and weighed as magnesium pyrophosphate ($\text{Mg}_2\text{P}_2\text{O}_7$).

The calculation is the same as for soluble phosphate. In the molybdic method the solutions are precipitated with ammonium molybdate as yellow ammonium phosphomolybdate, which is dissolved in dilute ammonia, and the phosphate precipitated with "magnesia mixture," as ammonio-magnesium phosphate, dried, ignited, and weighed as pyrophosphate ($\text{Mg}_2\text{P}_2\text{O}_7$); or the precipitate may be dissolved in a few drops of strong hydrochloric acid, and titrated in the usual way by a standard solution of uranic acetate.

It may here be remarked that all manures are sold on the basis of tri-calcium phosphate. Supposing, for instance, a manure contained 32 per cent. of soluble phosphate, calculated as tri-calcium phosphate, this would indicate that 32 per cent. of the original phosphate, either bone or mineral, had been made soluble by the treatment with sulphuric acid.

(8) SPECIAL OR MIXED MANURES.

These manures are mixtures of superphosphates with

varying proportions of nitrogen (either as organic nitrogen, nitrate of soda, or sulphate of ammonia) and potash.

(a) *Potash*.—The accurate estimation of potash in a manure is a very difficult operation, and requires great care on the part of the chemist. The following method, and one which is adopted by leading agricultural chemists, yields very good results:—

Weigh out 10 grams of the sample heat with 300 c.c. of water, add 1 c.c. of hydrochloric acid and barium chloride in slight excess. Pour off the liquor through a filter into a litre flask, repeat the digestion twice, allowing to settle, then place the whole on the filter, and wash and make up to the litre mark when cold. Take 50 c.c. (= .5 gram of the sample), and evaporate in a porcelain dish to 15 c.c.; when nearly to dryness, add sufficient platinic chloride (excess), and evaporate nearly to dryness, or to the thickness of a syrup, allow to stand half an hour, then wash by decantation with 80 per cent. alcohol; this is done for the purpose of dissolving the soluble sodium platinic chloride (Na_2PtCl_6); the decanted washings are passed through a filter. The crystalline residue is potassium platinic chloride (K_2PtCl_6). It is washed with alcohol to dissolve the excess of platinic chloride, and until no reaction for chlorine is seen in the filtrate; any crystals which may have passed on to the filter are dissolved in hot water, the solution being collected in a platinum dish and dried, to this is added the bulk of the precipitate and the whole dried at 130°C . and weighed as K_2PtCl_6 .

Example—

Weight of dish + K_2PtCl_6	. . .	22.241
Tare of dish	. . .	20.947
Weight of K_2PtCl_6 found	. . .	<u>1.294</u>

The factor for conversion of the K_2PtCl_6 into potash (K_2O) is .1938.

Then $1938 \times 1.294 = 2508$ the corresponding weight of potash, and as 50 c.c. (= .5 gram of the sample) was taken, the percentage = 5.016 (K_2O).

(b) *Soluble and insoluble phosphates* are found as in "Superphosphates" at (7) (a) and (b), p. 144.

(c) *Nitrogen*.—Nitrogen may be present (1) as nitrogenous organic matter; (2) ammonia; (3) nitrates.

The nitrogen in the organic matter is estimated by Kjeldahl's process. If nitrates are present these are eliminated by adding ferrous sulphate during the heating with sulphuric acid.

If ammonia is present, this is included with the organic nitrogen in the Kjeldahl process. To separately estimate it, another portion is weighed off, heated with milk of magnesia, the ammonia collected in standard acid and determined by titration with standard soda solution, as at p. 134.

The nitrogen in this is calculated and deducted from the total nitrogen, thus giving the organic nitrogen.

The nitrogen as nitrate is estimated by extraction with hot water, evaporation of the solution to 2 or 3 c.c. This is run into a Lunge's nitrometer, twice its volume of concentrated sulphuric acid added, any carbonic acid evolved being allowed to escape through the stopcock. The liquid is then shaken so as to bring it into intimate contact with the mercury, and, after evolution of gas ceases, the nitric oxide (NO) is measured and calculated to nitrogen.

1 c.c. of NO measured at 0° and 760 mm. pressure = .000627 gram of nitrogen.

(d) *Moisture*.—The hygroscopic or mechanical moisture is determined by heating the sample to $100^\circ C.$ till constant. The water of combination requires a temperature of 145° to $150^\circ C.$ for its removal.

(9) MINERAL PHOSPHATES.

Many classes of mineral phosphates come into the market,

and some of these the manufacturer uses as an admixture with ground boiled bones for superphosphate making.

Their value depends on the tri-calcium phosphate they contain, and this is estimated by dissolving a finely ground sample in strong hydrochloric acid, proceeding according to the method described under Insoluble Phosphates, p. 144.

(10) GUANOS.

Under this term are comprised a series of natural fertilisers, of which Peruvian guano may be considered the best example. Being perfect manures in themselves, they are used by the agriculturist unmixed with superphosphates. Their value depends on the phosphates and nitrogen they contain, the latter being in the form of ulmate, urate, chloride, and carbonate of ammonia. They are bought on a guarantee, and the works chemist is mainly called upon to estimate the soluble and insoluble phosphate and nitrogen the guano contains.

(a) The nitrogen existing as ammonia is estimated by distilling 2 grams of the sample with milk of magnesia in a flask connected with a Liebig's condenser, the volatile ammonia being passed into a standard normal acid solution, and then titrated with decinormal soda solution, as described, p. 135. The total nitrogen, in the absence of nitrates, is determined by Kjeldahl's method. If nitrates are present, the estimation is made according to the method given under "Special Manures," (8) (c), p. 146.

(b) The phosphates, both soluble and insoluble, are determined by the processes described under Superphosphates, p. 142.

(11) DRIED ANIMAL PRODUCTS,

such as blood, flesh, hoofs, and horns, etc., are sometimes used in a crushed condition, by the manure-maker, for enriching manures with nitrogen. They are bought on the

percentage of nitrogen, which is estimated in each case, on a finely divided sample, by Kjeldahl's method. The organic matter, ash, and moisture are determined, if required, by the processes already described under their headings.

(12) THE POTASH COMPOUNDS

used in the manure-shed are the chloride of potash and kainite, a mineral deposit obtained from Stassfurt, in Germany, containing some 23 to 25 per cent. of potassium chloride. The potash is determined by dissolving 10 grams either of the chloride or kainite in hot water, filtering into a litre flask, cooling, and making up to the mark at 15.5° C. Then measure out 50 c.c. for kainite (= .5 gram) or 10 c.c. for chloride (= .1 gram), and treat according to the method given under "Special Manures," (8) (a), p. 145.

(13) SULPHATE OF AMMONIA.

is the only ammonium salt used by the agriculturist. The ammonia is determined, as in guanos, in 2 grams of the sample, by distillation (but using soda in place of milk of magnesia), into a measured solution of normal acid, and then titrating with decinormal soda, from the resulting c.c. the ammonia and its equivalent, as sulphate, can be calculated.

(14) CHILI SALTPETRE.

(a) *Moisture*.—This is estimated by heating 5 grams in a porcelain dish to a temperature of 130° C. for one hour.

(b) *Nitric acid* (N_2O_5).—1 to 1.5 grams of the powdered saltpetre are weighed into a platinum crucible, mixed carefully with 7 to 10 grams of fine quartz sand (previously purified by treatment with hydrochloric acid, washed with water, and ignited), the mixture is slowly heated over a bunsen burner till it is red hot, and kept at this temperature for four hours. It is then cooled and weighed, again heated for half an hour and reweighed, this being repeated till constant. The loss equals nitric acid. In the above method the mixture of

nitrate and sand should not occupy more than one-third of the volume of the crucible.

Note.—It may here be remarked that the methods described in the preceding pages are sufficient for all commercial purposes; the buyer requires no more, neither does the seller; however interesting a full analysis of a manure may be from a scientific standpoint, it is scarcely ever required, the estimations being confined to those already described on which the values of the various manures are based.

INTERNATIONAL ATOMIC WEIGHTS.

Element.	Symbol.	Atomic Weight. 0 = 16.	Element.	Symbol.	Atomic Weight. 0 = 16.
Aluminium .	Al	27.1	Neodymium .	Nd	144.3
Antimony .	Sb	120.2	Neon . . .	Ne	20.2
Argon . . .	A	39.88	Nickel . . .	Ni	58.68
Arsenic . . .	As	74.96	Niton (radium emanation) .	Nt	222.4
Barium . . .	Ba	137.37	Nitrogen . .	N	14.01
Bismuth . .	Bi	208.0	Osmium . . .	Os	190.9
Boron . . .	B	11.0	Oxygen . . .	O	16.00
Bromine . .	Br	79.92	Palladium . .	Pd	106.7
Cadmium . .	Cd	112.40	Phosphorus .	P	31.04
Cesium . . .	Cs	132.81	Platinum . .	Pt	195.2
Calcium . .	Ca	40.07	Potassium . .	K	39.10
Carbon . . .	C	12.00	Praseodymium	Pr	140.6
Cerium . . .	Ce	140.25	Radium . . .	Ra	226.4
Chlorine . .	Cl	35.46	Rhodium . . .	Rh	102.9
Chromium . .	Cr	52.0	Rubidium . .	Rb	85.45
Cobalt . . .	Co	58.97	Ruthenium . .	Ru	101.7
Columbium .	Cb	93.5	Samarium . . .	Sa	150.4
Copper . . .	Cu	63.57	Scandium . . .	Sc	44.1
Dysprosium .	Dy	162.5	Selenium . . .	Se	79.2
Erbium . . .	Er	167.7	Silicon . . .	Si	28.3
Europium . .	Eu	152.0	Silver	Ag	107.88
Fluorine . .	F	19.0	Sodium	Na	23.00
Gadolinium .	Gd	157.3	Strontium . .	Sr	87.63
Gallium . . .	Ga	69.9	Sulphur . . .	S	32.07
Germanium .	Ge	72.5	Tantalum . . .	Ta	181.5
Glucinum . .	Gl	9.1	Tellurium . .	Te	127.5
Gold	Au	197.2	Terbium . . .	Tb	159.2
Helium . . .	He	3.99	Thallium . . .	Tl	204.0
Hydrogen . .	H	1.008	Thorium . . .	Th	232.4
Indium . . .	In	114.8	Thulium . . .	Tm	168.5
Iodine . . .	I	126.92	Tin	Sn	119.0
Iridium . . .	Ir	193.1	Titanium . . .	Ti	48.1
Iron	Fe	55.84	Tungsten . . .	W	184.0
Krypton . . .	Kr	82.92	Uranium . . .	U	238.5
Lanthanum .	La	139.0	Vanadium . . .	V	51.0
Lead	Pb	207.10	Xenon	Xe	130.2
Lithium . . .	Li	6.94	Ytterbium		
Lutecium . .	Lu	174.0	(Neoytterbium)	Yb	172.0
Magnesium .	Mg	24.32	Yttrium . . .	Yt	89.0
Manganese . .	Mn	54.93	Zinc	Zn	65.37
Mercury . . .	Hg	200.6	Zirconium . .	Zr	90.6
Molybdenum	Mo	96.0			

TABLE OF FACTORS FOR DETERMINING THE
EQUIVALENTS OF WEIGHED BODIES.

FOUND.	WANTED.	FACTOR.
Alumina (Al_2O_3)	Sulphate of alumina ($\text{Al}_2(\text{SO}_4)_3$)	3.350
	Potash alum	9.282
	Ammonia alum	8.870
Barium sulphate (BaSO_4)	Barium oxide (BaO)	.6570
	Barium carbonate (BaCO_3)	.8455
	Sulphuric acid (SO_3)	.343
Magnesium pyrophosphate ($\text{Mg}_2\text{P}_2\text{O}_7$)	Phosphoric acid (P_2O_5)	.638
	Tri-calcic phosphate ($\text{Ca}_3(\text{PO}_4)_2$)	1.3932
	Mono-calcic phosphate ($\text{CaH}_4(\text{PO}_4)_2$)	} 1.0515
	Bi-calcic phosphate ($\text{Ca}_2\text{H}_2(\text{PO}_4)_2$)	
	Magnesium sulphate (MgSO_4)	1.2223
	Magnesium chloride (MgCl_2)	1.0811
	Magnesia (MgO)	.8552
Potassic-platinic chloride (K_2PtCl_6)	Potash (K_2O)	.3621
	Potassium chloride (KCl)	1.938
	Potassium sulphate (K_2SO_4)	.3068
	Calcium sulphate (CaSO_4)	.3585
Lime (CaO)	Nitrogen (N)	2.428
Ammonia (NH_3)	Ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$)	} .8237
Ferric oxide (Fe_2O_3)	Iron (Fe)	3.883
Carbonic acid (CO_2)	Calcium carbonate (CaCO_3)	.6994
	Lime (CaO)	2.2886
Silver chloride (AgCl)	Chlorine (Cl)	1.2743
	Sodium chloride (NaCl)	.2473
	Sodium nitrate (NaNO_3)	.4078
Sodium sulphate (Na_2SO_4)	Sodium carbonate (Na_2CO_3)	1.1967
	Sodium oxide (Na_2O)	.7461
		.4364

TABLE OF THERMOMETRIC DEGREES.

CENTIGRADE.	FAHRENHEIT.	REAUMUR.
Freezing 0°	Freezing 32°	Freezing 0°
5°	41°	4°
10°	50°	8°
15°	59°	12°
20°	68°	16°
25°	77°	20°
30°	86°	24°
35°	95°	28°
40°	104°	32°
45°	113°	36°
50°	122°	40°
55°	131°	44°
60°	140°	48°
65°	149°	52°
70°	158°	56°
75°	167°	60°
80°	176°	64°
85°	185°	68°
90°	194°	72°
95°	203°	76°
Boiling 100°	Boiling 212°	Boiling 80°

RULES FOR CONVERSION.

$$\text{Fahrenheit to Centigrade: } \frac{5(F - 32)}{9} = C.$$

$$\text{Fahrenheit to Reaumur: } \frac{4(F - 32)}{9} = R.$$

$$\text{Centigrade to Fahrenheit: } \frac{C \times 9}{5} + 32 = F.$$

$$\text{Centigrade to Reaumur: } \frac{C \times 4}{5} = R.$$

$$\text{Reaumur to Fahrenheit: } \frac{R \times 9}{4} + 32 = F.$$

COMPARISON BETWEEN THE BRITISH AND
METRICAL SYSTEMS.

1 Pint = .5679 litre.	1 Mile = 1609.315 metres.
1 Gal. = 4.543 litres.	1 Lb. = 453.6 grams.
1 Inch = .0254 metre.	1 Lb. (Troy) = 373.24 grams.
1 Ob. in. = 16.386 ob. cms.	1 Cwt. = 50.8032 kgms.
1 Yard = .9144 metre.	1 Ton = 1016.064 kgms.
1 Metre = 39.37079 inches.	1 Kilogram = 2.2046 lb.
1 Litre = 1.76077 pints.	1 Kilometre = 1093.631 yds.

Conversion of	Multiplier.
Inches to metres . . .	.025399
Metres to inches . . .	39.37079
Square inches to square metres .	.0006451
Square metres to square inches .	1550.06
Cubic inches to cubic metres .	.0000163
Cubic metres to cubic inches .	61027.05
Gallons to litres . . .	4.543
Litres to gallons . . .	.22009
Pounds (avoirdupois) to grams .	453.592
Grams to pounds (avoirdupois) .	.0022
Pounds (Troy) to grams . . .	373.24
Grams to pounds (Troy) . . .	.002679

TABLE OF THE METRIC SYSTEM OF WEIGHTS AND
MEASURES.

LINEAR MEASURE.

10 Millimetres	= 1 Centimetre.
10 Centimetres	= 1 Decimetre.
10 Decimetres	= 1 Metre.
10 Metres	= 1 Decametre.
10 Decametres	= 1 Hectometre.
10 Hectometres	= 1 Kilometre.

The square and cubic measures are the square and cube of the linear measure respectively.

MEASURES OF CAPACITY.

10 Millilitres	=	1 Centilitre.
10 Centilitres	=	1 Decilitre.
10 Decilitres	=	1 Litre.
10 Litres	=	1 Decalitre.
10 Decalitres	=	1 Hectolitre.
10 Hectolitres	=	1 Kilolitre.

SYSTEM OF WEIGHTS.

10 Milligrams	=	1 Centigram.
10 Centigrams	=	1 Decigram.
10 Decigrams	=	1 Gram.
10 Grams	=	1 Decagram.
10 Decagrams	=	1 Hectogram.
10 Hectograms	=	1 Kilogram.

With water at its greatest density, *i.e.* 4° C.

1 Litre = 1 Kilogram, or 1000 cubic centimetres.

1 Gram = 1 Cubic centimetre of water at 4° C.

TANKS AND CISTERNS.

TO FIND THE CONTENTS—SQUARE OR OBLONG.

Reduce to inches, then multiply the length, width, and number of wet inches together for cubic inches, and convert the result into gallons by multiplying with .003604 or dividing by 277.463.

For every foot deep, a tank having the dimensions of

4 feet × 4 feet holds 99.698 gallons.

5	„	× 5	„	155.779	„
6	„	× 6	„	224.322	„
7	„	× 5	„	218.090	„
8	„	× 6	„	299.096	„
9	„	× 7	„	392.563	„
10	„	× 8	„	498.493	„

CIRCULAR.

Find the area of one end by multiplying the square of the diameter in inches by .7854, then multiply by the depth.

For every foot deep a circular tank

	4 feet in diameter holds 78·267 gallons.
5	" " 122·348 "
6	" " 184·936 "
7	" " 239·804 "
8	" " 276·314 "
9	" " 328·192 "
10	" " 384·286 "

The following data by Molesworth will enable a manufacturer to estimate the cost of any brickwork that may be required from time to time in his works :—

Thickness of Wall.	For Cubic Yards.	For 1000 Bricks.
1 brick	$A \times \cdot 02778$	$A \times \cdot 0106$
$1\frac{1}{2}$ "	$A \times \cdot 04167$	$A \times \cdot 016$
2 "	$A \times \cdot 0555$	$A \times \cdot 0213$
$2\frac{1}{2}$ "	$A \times \cdot 06944$	$A \times \cdot 0267$
3 "	$A \times \cdot 08334$	$A \times \cdot 032$

A = the superficial area of wall in square feet. The number of bricks in a cubic yard = 384.

1 load of mortar = 1 cubic yard.

1 cubic yard of brickwork requires } $6\frac{1}{2}$ cubic feet of sand.
about } $2\frac{1}{2}$ " of lime.

A wall, say, 20 feet \times 10 feet and 2 bricks thick would require —4260 bricks ; 72 cubic feet of sand ; 28 cubic feet of lime.

Frequently it is required to know the number of revolutions per minute of a wheel or pulley when driven by another of known diameter and speed. The rule is to multiply the number of revolutions and known diameter together, and divide by the diameter of the wheel or pulley of which the number of revolutions is desired. For example :—

Find the number of revolutions per minute made by a wheel 45 inches in diameter when driven by another 68 inches in diameter and making 62 revolutions.

$$\frac{68 \times 62}{45} = 93\cdot6, \text{ the required number of revolutions.}$$

APPENDIX A.

EVAPORATION IN VACUO.

DESCRIPTION OF A VACUUM PAN.

At the sea-level the average atmospheric pressure is 760 millimetres, equal to 29·922 inches of mercury in the barometer, or, in other words, a pressure of practically 15 lb. on the square inch; at this pressure water boils at a temperature of 212° F. (100° C.). As we ascend above this level, the atmosphere becomes less and less dense and consequently it exerts less pressure, as a consequence the boiling-point of water is reduced below 212° F. For instance, on the summit of Ben Nevis (4400 feet high) water boils at 203·9° F. (95·5° C.), while at an altitude of 15,800 feet (the summit of Mont Blanc) the boiling-point of water is lowered to 185·9° F. (85·5° C.).

An increase of atmospheric pressure, as, for instance, at the bottom of a deep mine, has the opposite effect, the thermometer recording several degrees above 212° F. before water actually boils.

If, then, the pressure on the surface of a liquid be reduced it has the effect of lowering the boiling-point of that liquid. On the other hand, if the pressure is increased above the normal, 760 millimetres, the boiling point is proportionately raised, as seen in the following table:—

	Pressure in lb. per square inch.	Pressure in atmospheres.	Boiling- point.
Below the normal pressure.	...	0·180	32·0° F.
	3	0·210	140·0° F.
	9	0·610	186·8° F.
Normal pressure at the sea-level.	15	1·020	212·0° F. (Boiling-point normal.)
Above the normal pressure.	22	1·500	234·5° F.
	30	2·040	250·5° F.
	45	3·060	275·7° F.

The variation of the boiling-point of water by increase or decrease of pressure has been turned to advantage in many manufacturing processes by the introduction of what is known as the vacuum pan, whereby under reduced pressure, produced by mechanical means, liquors containing easily decomposable substances can be concentrated without injury to the products which they contain. By working under a low pressure, clarified sugar juices, food extracts, glycerine, dye-wood extracts, gelatine, and other liquors can be concentrated to any desired extent without injury, whereas exposure to a temperature of boiling water for a prolonged period, such as would be required in evaporating in an open pan, would cause decomposition and affect them more or less injuriously. In 1813, Howard constructed the first vacuum pan, and since that time great improvements have been made in adapting it to modern requirements.

The pans now in use are built of wrought-iron, steel, or copper, and in form are either cylindrical or spheroidal. The latter shape finds favour in sugar refineries, and is made of two nearly hemispherical portions united at the centre by outside flanges. At the top is fixed the dome fitted with baffle-plates, to which is connected the condenser and vacuum pump. At the bottom is placed the discharge valve for the contents of the pan. The heating is carried out by an internal coil of pipes, or by a steam jacket round the lower half of the pan. The cylindrical form, built of wrought-iron or steel plates, is used for evaporating purposes in many processes, the pans of the double, triple, and quadruple effects, noticed further on, are also of this shape.

In Fig. 17 is seen an elevation of a vacuum pan for evaporating glue and gelatine liquors. The pan is built of steel plates, covered on the outside with wood, and rests on a floor constructed of rolled steel plates, supported on four columns, with a stairway leading to the working platform. One-half of the lower part is shown in section, giving a view of the coil by which the pan is heated. The various parts are as follows:—

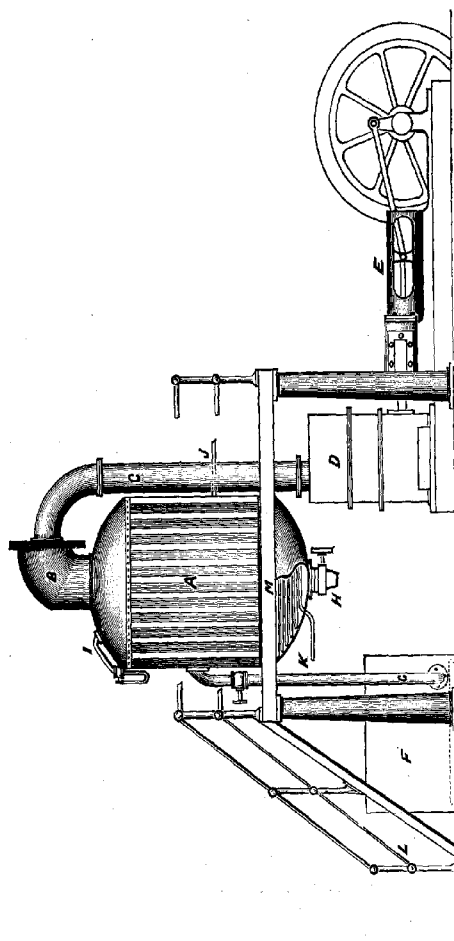


FIG. 17.—Vacuum Pan.

- A.* The body of the pan.
- B.* The dome.
- C.* Exhaust pipe leading from dome to condenser.
- D.* Condenser.
- E.* Air or vacuum pump.
- F.* Storage tank for glue or gelatine liquors, warmed with steam coil.
- G.* Supply pipe leading from storage tank to vacuum pan.
- H.* Discharge valve.
- I.* Barometer gauge for indicating vacuum.
- J.* Inlet steam pipe for supplying the coils.
- K.* Exhaust end of vacuum coils.
- L.* Iron staircase.
- M.* Steel floor.

The accessories connected with the pan are placed in a convenient position above the working floor, and include a steam gauge for noting the pressure in the coils, a gauge for indicating the height of the liquor in the pan, vacuum gauge *I*, as shown in the drawing, air-cocks and a thermometer. The pan is also fitted with a small apparatus, by which portions of the boiling liquor can be withdrawn from time to time, without destroying the vacuum, so that the progress of evaporation can be ascertained.

In working the pan, the storage tank *F* is first filled with the weak glue liquors to be evaporated; the valve on the supply pipe *G* is then closed, and the vacuum pump set in motion; a few strokes being sufficient to reduce the internal pressure, the valve of the supply pipe is then opened, and the liquor allowed to flow into the pan to the desired mark on the gauge. The valve is then closed, and the steam inlet valve *J*, supplying the coils, opened. As the heat from the coils spreads through the liquor, the vacuum pump is kept steadily at work reducing the internal pressure within 2 to 2½ inches of a perfect vacuum, as seen on the vacuum gauge. At this reduced pressure the liquor boils at 120° to 130° F., and the boiling is continued until the samples withdrawn and tested by the glue-meter show the desired strength.

The pump is then stopped, the vacuum broken by opening the air-cocks, and the concentrated liquor is run through the valve *H* into suitably arranged receiving tanks, for supplying the trays or glasses for jellying.

For economical working with large quantities of weak liquors, a combination of two, three, and even four vacuum pans, forming the double, triple, and quadruple effect evaporators, have been designed for concentration purposes. The triple effect is, however, the system mostly in use, and consists of a grouping of three cylindrical pans, each connected by suitably arranged piping, by which the vapours of the first pan are conveyed to and made to heat the coils of a second pan, the resulting vapours from the second passing on to a third pan, for a similar purpose. All the pans are connected with powerful pumps, so that an almost perfect vacuum is maintained in each. The liquor is evaporated to a given density in the first pan, then passed on to the second, and ultimately to the third, at which stage 80 per cent. of its water will have been driven off.

APPENDIX B.

GELATINE.

COMPARISON BETWEEN FRENCH AND BRITISH GELATINES.

THE following is a comparison of various brands of British and French makers of Gelatine, showing the ash and water absorption, the latter indicating the economical value. The water absorption is on one gram.

Brand.	Ash.	Water absorption of 1 gram of sub- stance taken. Grams.
Coignet's Gold Label Gelatine .	1 per cent.	12.0
Coignet's Special	1 „	12.0
Nelson's No. 1 Photographic Gelatine	2 „	10.0
Ordinary French, not branded .	2 „	10.33
Cox's Gelatine in Packets .	1 „	9.86

Undoubtedly the superiority of the French in the production of Gelatines rests on the great care exercised in the selection of raw material, and the close scientific supervision of every operation. The crystal White Leaf Gelatine is made from a careful assortment of the cuttings of prepared skins used in the manufacture of white kid gloves. Such a product realises £190 to £200 per ton.

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